Blue-sky Thinking:

Flood Risk Management and Blue-Green Infrastructure in Brisbane and Singapore

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Abstract

Floods are caused by a wide range of meteorological and environmental factors and issues around infrastructure and land use, resulting in various environmental, social and economic ramifications for societies. Brisbane, Australia, is a key example of a highly urbanised and dense city that is threatened by floods due to its location on the Brisbane River floodplain, which also exposes it to a myriad of sub-tropical climatic patterns. Hence, flood risk management strategies are used by authorities, institutions and communities to address and mitigate potential flood risks. However, the unpredictable nature of floods, diverse priorities of governments and differing institutional structures hinder the development of a standard framework for flood risk management thus different combinations of approaches are used to suit the local context. Moreover, technology and knowledge advancements have led to growing global shift towards using more nature-based solutions such as Blue-Green Infrastructure (BGI) to help support current flood risk management efforts.

This research aims to explore the flood risk management strategies used after the 2011 Brisbane floods and to investigate the capacity for BGI in this management. A qualitative approach was used to investigate the primary case study of Brisbane in comparison to the secondary case study of Singapore, another high-density city that experiences flooding and incorporates BGI within its flood risk management at a national scale. As there are different mechanisms used to mitigate flood risks, it is important to identify how BGI can be implemented to effectively support existing infrastructure. Research methods included a literature review around flood risk management, BGI and the contexts of Brisbane and Singapore; a detailed analysis of planning and policy documents; and semi-structured interviews with academics, consultants and Brisbane City Council (BCC) staff.

The analysis of policy and planning documents identified that flood risk management strategies differed according to the individual document's purpose, wherein the BCC uses more types of strategies and incorporates a medium to high level of BGI in their documents compared to the Queensland (state) and Australian (federal) Governments. Although there is considerable incorporation of BGI in the BCC's plans there is still significant overlap in the Queensland Government's policies, hence the planning environment and its documents would benefit from being streamlined for clarity.

In contrast, the Singapore Government's documents and approaches demonstrated consistent strategic preferences within a centralised integrated stormwater management approach with a high level of BGI integration throughout. Interview findings highlighted the value of the BCC's flood risk management strategies but called for more accuracy, with the effectiveness hindered by complex challenges of differing levels of risk perception and literacy; deficiencies in planning and decision-making processes; and strong development pressures. Existing BGI initiatives such as that of Oxley Creek and Norman Creek were seen to be successful, albeit slow in growth. This slow uptake was suggested to be due to vested interests, funding constraints, and a lack of clarity in its maintenance and communication of its benefits. Singapore's flood risk management approach, conversely, was noted for its centralised and proactive governance, planning efficiency, stable funding and efficient public communication, although public involvement needed to be improved upon. Singapore's Active, Beautiful, Clean Waters Programme was highlighted as an example of a successful national BGI initiative for Brisbane to formulate approaches that can be implemented at a wider scale.

Brisbane and Singapore have demonstrated different strengths and weaknesses in terms of flood risk management and BGI. Flood risk management in Brisbane, particularly its BGI implementation, can be improved with learnings adapted from Singapore's strengths, and vice versa. The BCC has demonstrated significant efforts in diversifying its strategies and enhancing the level of BGI to address flood risks, however for these efforts to persist, local and state government decision-makers should also address political priorities that favour development over flood risk planning, provide more robust flood risk management controls and risk indicators, and work towards transitioning to more holistic and integrated flood risk management frameworks.

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List of Abbreviations

ABC Waters Programme	Active, Beautiful, Clean Waters Programme
AEP	Annual Exceedance Probability
BGI	Blue-Green Infrastructure
BCC	Brisbane City Council
BMPs	Best Management Practices
CLC	Centre for Liveable Cities
COP	Code of Practice on Surface Water Drainage
DILGP	Department of Infrastructure, Local Government and Planning
DMA	Disaster Management Act
EPDDFPM	Expert Panel on Drainage Design and Flood Protection Measures
HDB	Housing and Development Board
IUWM	Integrated Urban Water Management
LDMP	Local Disaster Management Plan
LID	Low Impact Development
MSOF	Managing Stormwater for our Future Publication
MSS	Meteorological Service Singapore
NDRRF	National Disaster Risk Reduction Framework
NFRAG	National Flood Risk Advisory Group
PWD	Public Works Department
PUB	Public Utilities Board
QFCI	Queensland Floods Commission of Inquiry
QRA	Queensland Reconstruction Authority
SEQ	South East Queensland
ShapingSEQ	ShapingSEQ – South East Queensland Regional Plan 2017
SPF	Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience
SPP	State Planning Policy
SUDS	Sustainable Urban Drainage Systems
WDP	Waterbodies Design Panel
WSUD	Water Sensitive Urban Design
URA	Urban Redevelopment Authority

1 Introduction

1.1 Introducing Flood Risk Management and Urban Planning

Floods are one of the most common hazards to occur worldwide, and can culminate in minor to extensive socio-economic and physical impacts in the affected areas (UN-Habitat, 2015; Ghofrani *et al.*, 2016). There are a variety of causes that trigger flooding, such as heavy rainfall and intense weather events, modification of river systems, increasing urbanisation, inadequate drainage infrastructure and climate change (UN-Habitat, 2015; Salathé & Mauger, 2018; Xue *et al.*, 2018). The increasing frequency of major floods around the world demonstrate a need to seek and implement other more resilient management strategies beyond conventional grey infrastructure that can adapt to the variable nature of floods, reduce flood risks and conserve the environment (Liao, 2012).

Flood risk management uses structural and non-structural methods (Corotis, 2018; UN-Habitat, 2015) which can administer within the broad strategies of flood risk prevention, flood defence flood risk mitigation, flood preparation and flood recovery (Raadgever *et al.*, 2018). There is a growing consensus and shift in flood risk management towards a more holistic and risk-oriented mindset that will help authorities to plan more effective frameworks towards managing and reducing flood risks (Schanze, 2006; Gruntfest & Handmer, 2001). The ranging intensity and unpredictability of floods and their impacts makes it difficult for government bodies to plan for floods, with some places even lacking in adequate flood management infrastructure and flood response strategies (UN-Habitat, 2015). Hence, flood risk management frameworks will differ amongst the governments that develop them, making it challenging to replicate solutions for other places, but also provides opportunities to innovate and adapt (Raadgever *et al.*, 2018).

Planning robust flood risk management frameworks that have appropriate strategies to mitigate risks of various flood types are especially challenging in dense cities such as Brisbane, Australia (Liao, 2012), which is the site of the primary case study for this thesis. Over the years, there has been a shift towards more sustainable and adaptable forms of water management (Wong & Brown, 2009), one of which is the concept of Blue-Green Infrastructure (BGI). BGI integrates natural systems and utilises natural engineering technology to construct infrastructure that provides a host of benefits including flood control and water storage (Drousou *et al.*, 2019; Ahmed *et al.*, 2019; Lawson *et al.*, 2014). Some cities have adopted BGI to support their current infrastructure in managing stormwater so as to mitigate flood risks. A prominent example is the secondary case study for this research, Singapore, which is regarded as a best-practice model for its BGI-embedded integrated stormwater management approach (Wong & Brown, 2009; Public Utilities Board, 2014; Centre for Liveable Cities, 2017).

The existing literature showcased different ways of planning and implementing flood risk management; the thesis will explore two case studies, Brisbane and Singapore, where there are differences in the governance structure and institutional approaches for flood risk management areas, the relative importance they attach to public communication and the availability of transparent documents. Additionally, the thesis will demonstrate how these two case studies develop effective strategies towards managing flood risks, and the differences in decision-making at the government and community level. The locus of planning is also an important point ascertained through the research, where governance and flood risk planning in Brisbane functions at multiple levels while in Singapore, a centralised approach is taken, which subsequently affects how flood risk management and BGI is conducted as a whole.

1.2 Research Rationale

The variation of flood types that occur depends on the geographic location; topography; meteorological factors; and the availability, type and quality of grey infrastructure for stormwater management; hence governments have to develop solutions that are catered to their local contexts. Brisbane presents a suitable case study for the exploration of this research as its political landscape and the continual pressures of urban expansion is at odds with its variable climate and location on a floodplain (Spearitt, 2009; Gleeson *et al.,* 2010). The inevitability of floods in Brisbane highlights the need for more adaptive and effective flood risk management and mitigation. The most recent major flood to occur was the 2011 Brisbane floods; where a large body of literature recounts and assesses the complex issues that led up to the occurrence of the floods (Van den Honert & McAneney, 2011; Tangney, 2015, Cook, 2019). While the literature primarily covers the causes of the 2011 floods, when it comes to understanding the institutional responses and implications for subsequent flood risk management responses to this, there is still a significant gap in the research.

Indeed, there is considerable variability in the research conducted on flood risk management strategies, measures and planning processes used by the Brisbane City Council and the Queensland Government (Bajracharya & Khan, 2020; Pennisi & Perera, 2017; Tangney, 2015). Assessing the performance of the BCC in the management of Brisbane's flood risks is complex because the BCC has a wide range of institutional responsibilities for different aspects of city's growth. Hence, I am also seeking to identify how the Brisbane City Council's (BCC) scale affects the management of Brisbane's flood risks. While keeping in mind the complexity of this topic which is less understood by the general public, it is important to note that this topic has long-term impacts in planning and governance. Furthermore, the literature indicates that the effectiveness of BCC's institutional processes and planning are affected by socio-political tensions between the Queensland Government, the private sector and the community. However, there is an information gap in how these issues consequentially impacts upon the effectiveness and efficiency of flood risk management and the implementation of BGI to mitigate flood risks. It was determined that there is still a lack of research in the following areas:

- How the Australian governance system impacts upon the planning processes of Brisbane’s flood risk management;

- An in-depth look on the effectiveness of planning and policy documents that regulate Brisbane’s flood risk management;

- An overview of the extent of BGI efforts present within Brisbane to help mitigate floods.

Hence, this thesis argues that there is an opportunity within this research to assess how the various levels of governance and planning processes contribute to Brisbane’s flood risk management. In doing so, the thesis analyses how these processes can be improved and also investigates the extent and future capacity of BGI to be used in flood risk management within Brisbane. Singapore is chosen to provide a comparative model against Brisbane to understand the reasons and challenges to effective flood risk management and BGI implementation, and provide areas of learning.

1.3 Research Aim and Questions

The overarching aim of the thesis is to assess the flood risk management strategies used after the 2011 Brisbane Floods and to evaluate the potential for a wider implementation of BGI in Brisbane’s flood risk management so as to improve the city's liveability and sustainability on the floodplain. In particular, I am also exploring how Singapore's integrated approach to flood risk management using BGI can provide learning opportunities for Brisbane's flood risk planning. The research questions that will drive the research are as follows:

1. *How do the planning processes of Brisbane and Singapore contribute to the development of their flood risk management approaches?*

2. *What are the issues and limitations of Brisbane City Council's planning processes that affect flood risk management?*

3. *How and to what extent can blue-green infrastructure be used as a more resilient and sustainable option for Brisbane's flood risk management and what are the barriers to the implementation of this infrastructure?*

1.4 Thesis Structure

The thesis structure is structured in a manner that examines floods, flood risk management and BGI on a broad scale, before going into a specific focus on Brisbane and Singapore to address the research aim and questions.

Chapter 2 firstly develops a broad understanding of floods, its impacts and the common flood risk management strategies. This chapter also addresses the lack of a general flood risk management framework due to the fluctuating nature of floods and the differing priorities of governments around the world. Hence, a general overview of flood risk management strategies was derived from the available literature to help guide the development of the research. The literature review reflects how we respond to floods, where there is a common consensus that a mixture of structural and non-structural measures is needed to provide for a robust flood risk management framework, as such, these frameworks are adaptable and specific to the contexts they are to be applied in. This is helpful in understanding how flood risk management frameworks are developed in Brisbane and Singapore. The concept of BGI and its use within flood risk management is also defined in this chapter, providing a background to the different ways BGI can be implemented to support current measures in managing and mitigating of floods, while also demonstrating the global shift towards more adaptable and sustainable forms of dealing with flood risks.

Chapter 3 describes the methodology and rationale used in this research. This research uses a qualitative, dual case study approach, with Brisbane being the primary case study and Singapore being the secondary case study. Research data was collected through semi-structured interviews with informants who consisted of academics, consultants and Brisbane City Council (BCC) staff and a review of academic and grey literature. The interviews questions were designed to understand the effectiveness of the current strategies used by the BCC, issues that affect the Brisbane's flood risk management system and BGI implementation, and areas of learning for Brisbane through a comparison with Singapore's integrated stormwater and BGI approach. Supported with an analysis of planning and policy documents from Chapters 6 and 7 (which also included visual materials), these questions identified that the breadth of BCC's strategies was acknowledged by academic and consultant informants. However, academic and consultant informants were more critical than BCC staff over the strategies' effectiveness and identified specific governance and socio-political issues that hinder robust flood risk management and wider BGI applications. These informants also highlighted various aspects of Singapore's governance and planning approach that would be beneficial for Brisbane to adapt. Ethical considerations, positionality and limitations of this research were also addressed in this chapter.

The case studies of Brisbane and Singapore are subsequently addressed in Chapters 4 and 5 respectively, which form the foundation towards understanding the specific contexts to which their flood risk management systems are developed upon. Chapter 4 explores Brisbane in detail, covering the geographical and climatic factors that contribute to floods, the flood history and flood types, the major floods of 2011 that have led to a reconsideration of flood risk management strategies and the nature of urban planning and governance in Brisbane. Chapter 5 delves into the Singapore context, examining the geographical and climatic factors that lead to flooding, its flood history, its urban planning and governance approach that has redeveloped how the country plans for flood risks and the current flood risk management efforts.

The thesis then turns to an explicit description an analysis of results of the primary and secondary section. Chapter 6 and 7 assesses the various planning and policy documents that pertain to flood risk management and, the planning and implementation of BGI in Brisbane (at all levels of government) and Singapore respectively. Chapter 7 also includes a comparative analysis between the documents from both case studies to understand the scope of flood risk management and the extent of effective BGI implementation. This analysis was firstly conducted through scoring schemes that I developed to assess all planning and policy documents and approaches using five criteria for flood risk management and six criteria for the effectiveness of BGI implementation. These criteria were derived from the literature review. Written analyses then follow the scoring schemes to interpret the results obtained from the scores. These chapters demonstrated that flood risk management strategies vary depending on the purpose that each document is trying to achieve; there is however, a need for Australian documents to be streamlined for increased clarity. BGI was observed to be more strongly planned for in the local level documents of Brisbane, while documents from Singapore tended to demonstrated a high level of BGI planning due to the country's integrated planning approach.

The results obtained from the key informant interviews are presented in Chapter 8, analysing in detail the perspectives on the effectiveness and limitations of measures used to manage and mitigate flood risks, the barriers to effective flood risk management and the challenges of BGI integration in Brisbane. The suitability and areas of improvement needed for effective implementation for BGI in Brisbane is also explored. This chapter also investigates the informants' views that compare Singapore and Brisbane's flood risk management and BGI approaches to derive learning areas for Brisbane. BCC's existing flood risk management strategies were deemed to be effective to an extent but was largely affected by the lack of accuracy and transparency, while major issues that impacted the framework were from varying levels of public risk literacy and flood memory, deficiencies in planning and decision-making processes and strong development pressures. Although there has been a slow growth of BGI applications for flood risk management in Brisbane, projects such as Oxley Creek Transformation and Norman Creek were seen to be successfully established examples that suited Brisbane. Several issues that impacted the growth of BGI were pressures from vested interests, funding constraints; demonstrating effectiveness; lack of clarity around responsibilities and communication; and low political will, institutional efficiency and innovation. Through a comparison with Singapore's approach, it was observed that centralised and proactive governance, strong political will and institutional efficiency to planning, funding stability, strong multi-agency collaborations and efficient public communication were key to Singapore's robust approach to managing flood risks that placed high importance on integrating BGI throughout. These were areas that Brisbane could learn from and adapt to suit the local context.

Lastly, Chapter 9 discusses and concludes the research. Based on the results from Chapters 6 and 7, the research acknowledges the breadth of measures available to address flood risks from the national to the local level in Brisbane and the national level in Singapore. Flood risk management strategies differ based on the purpose of each document and approach, where a single or combination of strategies may be chosen. Due to overlapping content in the state level documents (Queensland Government) in relation to Brisbane, more clarity is needed to better structure flood risk management strategies and actions, and provide clearer guidance to decision-makers. Local level documents (Brisbane City Council) in relation to Brisbane provide more specificity and utilise a wider range of strategies and have a higher level of planning and incorporation of BGI compared to that of the state and national levels.

Similarly, based on the results of Chapter 8, the research found that the range of flood risk management strategies were seen to be adequate however informants argue that differing levels of risk perception and literacy, deficiencies in the planning and decision-making processes, development pressures, and insufficient accuracy and proactiveness are issues that need to be addressed for Brisbane's flood risk management and BGI implementation to be improved. Similarly, BGI implementation was largely supported by informants, particularly for flood risk management in Brisbane to shift towards a holistic integrated approach, where community involvement was found to have driven some significant BGI initiatives. Although community involvement is less robust in Singapore, the case study's strengths were found to be its centralised governance approach to flood risk management and planning, robust leadership and political, proactiveness, stable funding, strong multi-agency partnerships and public communication, allowing the country to be able to roll out drainage infrastructure and a national BGI programme to respond to flood risks. The research also acknowledged the areas of difference between both case studies but recognised the transferability of the strengths of Singapore's flood risk management and BGI approaches, which can help Brisbane to upgrade its strategies and enhance its resilience to flood risks in future.

2 Literature Review

The increasing occurrence of floods as a result of climate change and expanding urbanisation presents a constant need for flood risk management to improve and adapt, in particular the infrastructure and the policy and planning frameworks used. The inevitability of flood events indicates the importance to shift towards more sustainable and environmentally based approaches that utilise natural processes to regulate water flow. The literature review aims to analyse the current literature on flooding, flood risk management and Blue-Green Infrastructure (BGI) and in particular how BGI approaches have been considered in flood planning. Flooding and its impacts will be explored in the first section. The second section will explore the current methods of flood risk management and their impacts. Specific best practice examples from different parts of the world will be described and analysed in this section. In doing so, the approaches of Brisbane and Singapore can be placed within a broader context of global experiences.

2.1 Introduction to Floods

Experienced globally, floods are a common hazard event where water bodies are unable to bear and cope with the accumulation of high levels of water, subsequently overflowing onto the surrounding areas (UN-Habitat, 2015). Flooding is a natural occurrence in places with riverine systems as part of their topography, for example Myanmar, China, India and Canada (UN-Habitat, 2015). Urban environments can be particularly prone to flooding events during adverse weather (Ahmed *et al.*, 2019; Voskamp & Van de Ven, 2015), where urban areas near rivers can be affected by riverine floods that are caused by the inundation of rivers and their tributaries from prolonged rainfall (UN-Habitat, 2015; Brisbane City Council, 2019). Flood vulnerability in settlements can also occur as a result of being situated downstream, in lower areas of a river catchment, or downstream from dams (Corotis, 2018). This vulnerability can increase when such structures experience heightened hydraulic pressured or lack long-term maintenance and their ability to function appropriately is reduced (Corotis, 2018).

The UN-Habitat (2015) lists the following as key causes of flooding events: constant and heavy rain, obstruction of river channels, narrow river channels, altered river flows, poor design of grey infrastructure, the malfunction of stormwater control measures and urbanisation that lack drainage systems. River bed sedimentation, deforestation, and the removal of trees and mangroves that assist in erosion-prevention, are also considered key contributors to floods (UN-Habitat, 2015). Other causes of floods are, damage to hydraulic systems, earthquakes and rising water level where the sea meets rivers (Smart, 2016). Moreover, climate change exacerbates severe rainfall, elevates sea levels, increases wildfires which destroys riparian vegetation and increases landslides which modifies stream channels (Salathé & Mauger, 2018). Other severe weather events such as cyclones, tornados and hurricanes also occur with floods, elevating the severity and aftermath of floods (Xue *et al.*, 2018). Since flooding is caused by both physical environmental processes and man-made activities, their impacts on their surrounding environment can range from minor to destructive.

2.2 Flood impacts

Floods, especially flash floods, can be highly destructive to infrastructure, the environment, properties, and businesses (Gruntfest & Handmer, 2001; Ghofrani *et al.*, 2016; Ashley *et al.*, 2005). Moreover, residents in flood-affected areas will experience disruptions to their daily lives (Ashley *et al*., 2005; Gruntfest & Handmer, 2001), casualties from drowning, and suffer from disease outbreaks due to the contamination of water supplies and damaged wastewater networks (UN-Habitat, 2015). Food shortages may subsequently occur due to damaged crops and food stores in addition to the inundation of agricultural areas (UN-Habitat, 2015). Furthermore, residents that have experienced flooding events can develop flood-related trauma that may last for a period of time and result in a diminished sense of security (Gruntfest & Handmer, 2001). Floods and their associated impacts can be extended and amplified if rainfall events continue over a prolonged period and reoccur frequently (Najibi & Devineni, 2018).

Urban areas with river networks situated within or near them are highly vulnerable to flooding as flood waves can occur both upstream and downstream. Stormwater networks such as water channels and drains that are located downstream can experience backflows from flood waves which often result in flooding of nearby properties (Ashley *et al.*, 2005). The advancement in technology used in flood risk management such as forecasting, early warning systems and flood management infrastructure in recent years, have led to a decrease in the number of casualties suffered from flood events (Najibi & Devineni, 2018). It should be noted that there still is a lack of research around determining the aggregated effects on flood risk from river floods, storm surges and increasing sea levels (Salathé & Mauger, 2018).

2.3 Flood Risk Management

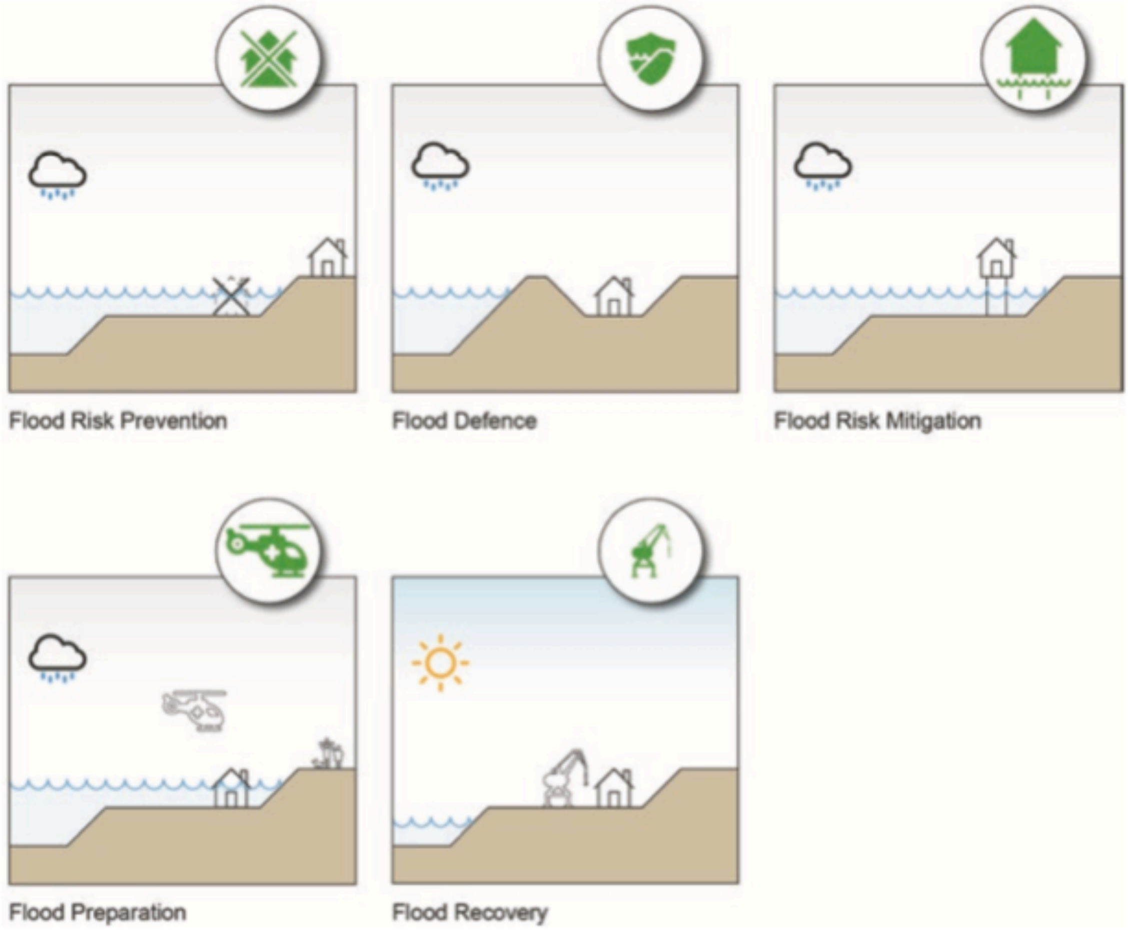
The risk of flooding is influenced by the rate of flood occurrences and the resulting impacts on the affected inhabitants as noted by National Flood Risk Advisory Group (NFRAG) (2008). Flood risk management and mitigation strategies help to assess flood risk and generate emergency strategies and suitable mitigation approaches to alleviate flood frequency and the impacts of floods for the long-term (Commonwealth of Australia, 2009; UN-Habitat, 2015; NFRAG, 2008). Mitigation and management of flood risk and flood events are often complicated, challenging and expensive tasks that authorities have to undertake. With the current development in technology and knowledge however, identifying flood locations, their rate of occurrence, the level of community impact and other possible damages are much more available and feasible (Commonwealth of Australia, 2009).

Practices used within flood risk management can be categorised as structural and non-structural methods. Structural types typically comprise of man-made infrastructure such as raising the foundations of houses, embankments, by-pass channels and irrigation systems (UN-Habitat, 2015). Non-structural measures are typically established with the involvement of the authorities and the community, such as flood planning, flood risk awareness, disaster risk training and modifying farming practices, government intervention strategies and community participation (UN-Habitat, 2015). Regulations, strategies and policies in particular are non-structural measures that are typically initiated by the authorities (UN-Habitat, 2015) and primarily operate from the government level before moving to the local level.

Corotis (2018) highlights that the use of structural measures can affect public expectations of their performance and contribute to widely held beliefs that floods are preventable. As such, this way of thinking should be cautioned against as structural approaches offer varying levels of flood mitigation and are not guaranteed to be absolute defences against floods. Corotis (2018) notes that communities may have some disaster risk knowledge, however they are unlikely to have in-depth knowledge about grey infrastructure and their uses in hazard-mitigation, or the risks that these structures may not perform as expected during intense weather events, thereby increasing their susceptibility to floods. Moreover, authorities need to take into account that communities may not fully appreciate the extent of impacts from floods to structural and socio-economic infrastructure (Corotis, 2018). For example, certain flood management measures may lack effectiveness against flash floods due to its volatile nature, unpredictability of flooding locations and the constraints of stormwater networks to accommodate sudden increases in rainfall (Gruntfest & Handmer, 2001). It is globally understood, therefore that flood risk management necessitates the use of both structural and non-structural methods to reduce the likelihood of and the impacts of floods (Raadgever *et al.*, 2018). Combining these methods is likely to decrease building and infrastructure damage, increase effective responses by the public and government, accelerate flood recovery (BoM, 2009) and increase the adaptability to the flood types experienced within a location.

There is a broad range of literature around floods and various measures to regulate and alleviate flood risks, however there is some contention around the categorisation of these measures, showing the change over time in our understanding of flood risk management. Hence, to understand the different ways which these measures deal with flood risk, I referred to literature from Raadgever *et al.* (2018) which provides a succinct classification that categorises these measures into broad strategies according to their main functions: flood risk prevention, flood defence, flood risk mitigation, flood preparation and flood recovery, as illustrated in Figure 2.1.

Figure 2.1 Flood Risk Management Strategies



Note. Flood risk management strategies (image source: Raadgever *et al.*, 2018).

These five strategies encompass the various structural and non-structural methods commonly used to manage flood risk (Raadgever *et al.*, 2018; UN-Habitat, 2015; NFRAG, 2008; Australian Institute of Disaster Resilience, 2009); this is visualised in Table 2.1, and will be further explored in the following sections. It is important to note that different authorities place different emphasis on each of these strategies and their respective methods depending on the context and time period that is required, this will be further explained in section 2.4.

Table 2.1 Overview of Flood Risk Management Strategies

Flood Risk Prevention	Flood Defence	Flood Risk Mitigation	Flood Preparation	Flood Recovery
Land use planning	Flood protection	Flood proofing	Flood forecasting and warnings	Reconstruction plans
Building regulations and codes	Flood reduction	Flood zoning	Community awareness, education	Flood insurance
	Flood diversion	Flood modelling and mapping	Flood management and evacuation plans	Compensation

Note. Overview of flood risk management strategies and their structural and non-structural approaches.

2.3.1 Flood Risk Prevention

Flood risk prevention involves practices that prevents building in areas with flood risks so that inhabitants and buildings are less likely to be exposed, thereby reducing the impacts suffered from floods (Raadgever *et al.*, 2018). Such practices include land use planning, building regulations and codes, which will vary in application depending on the location and the policy choices of the authorities that develop and implement them. The following sections will provide the functions and effectiveness of these flood risk prevention strategies to help understand how they can contribute to managing flood risks.

2.3.1.1 Land Use Planning

A significant aspect of planning for floods revolves around land use planning, also known as zoning. The configuration and sites of developments and land zoning are identified within land use planning, which can then be used to inform and direct urban growth towards less vulnerable areas, as well as regulate floodplain development (UN-Habitat, 2015; Commonwealth of

Australia, 2009; Australian Institute of Disaster Resilience, 2009). Regulating land use and decreasing population densities in flood-prone areas will decrease the number of residents exposed to future flooding events which subsequently diminishes risk (UN-Habitat, 2015). An example of that would be the deterrence of extensive developments by authorities in locations that are at exposed to severe or frequent flooding (Raadgever *et al.*, 2018; UN-Habitat, 2015). Other land use planning policies can include specific building regulations, providing major drainage infrastructure, designating vulnerable locations as conservation areas or leisure spaces, and expanding the area for the river to improve their discharge (Corotis, 2018; Hudson & Botzen, 2019). In flood-prone areas that have been developed, authorities may consider relocating residents to safer locations and providing vital services in secure locations, in addition to implementing flood emergency plans (UN-Habitat, 2015; Australian Institute of Disaster Resilience, 2009). It is important to note that these strategies require the execution of rigorous land use planning policies and rules, which can help to lessen illegal riverside development that could modify river flow and direction and cause cascading effects on settlements further along (UN-Habitat, 2015; Australian Institute of Disaster Resilience, 2009). It is essential that authorities plan for floods as it allows money and labour to be invested in flood management and provides the potential to mitigate physical damages to housing and infrastructure when future floods occur (Commonwealth of Australia, 2009). Stakeholders are especially important in planning for flood-prone land use as they are often individuals and groups that are involved or affected by development and flood risk (Corotis, 2018; UN-Habitat, 2015), therefore their input and collaboration can be helpful in designing and initiating effective policies and strategies.

Flooding, along with climate change, not only affects the subsequent management and regulation of land but also affects policy sectors that already have "established organisational processes" (Bruzzone, 2013, p. 2002), requiring a shift in governance, political and social arrangements and to embrace adaptive methods that can address natural hazards and phenomena alongside urban and population changes (Bruzzone, 2013). Bruzzone (2013) notes challenges are faced by policymakers in terms of establishing improved local interventions and "adaptive public policies" (p. 2002) and suggests exploring "beyond indicators and future scenarios" (p. 2002). Public awareness and effective mitigation of urban flooding can often encounter political and planning-related obstacles, wherein development is still given the go-ahead even if the area is prone to flooding (Ashley *et al.*, 2005). Bruzzone (2013) suggests that such hazard events and climate change should be the centre of focus therefore, adaptation practices should work across various sectors and encourage participatory planning processes rather than top-down approaches.

2.3.1.2 Building Regulations and Codes

Flood adaptability can be enhanced through building regulations and codes which highlight flood-prone land, prevent development in areas at risk, or establish suitable building and design procedures needed to increase their resilience against severe weather events (UN-Habitat, 2015; Australian Institute of Disaster Resilience, 2009; Ministry for the Environment, 2008). Building controls cover a range of features such as building location, foundation, minimum height, layout, structure, walls and roofs (UN-Habitat, 2015; Commonwealth of Australia, 2009). Some examples for flood-resistant configurations include building on higher and more stable locations, steering clear of natural flow paths and waterbodies, raising building foundations, using robust pillars and bracing in building structures and sturdy flat roofs that are higher than predicted floods (UN-Habitat, 2015; Bureau of Meteorology, 2009; NFRAG, 2008; Corotis, 2018). Building regulations and codes are often provided within city plans as part of increasing flood resilience and reducing flood risks; such criteria is seen in New Zealand and Australia (Dunedin City Council, 2020; Brisbane City Council, 2014). Additionally, building regulations can be presented through building manuals that guide people on cost-efficient and robust building methods, which has been supplied to places such as Cambodia, Bangladesh, Pakistan and Burma (People in Need, 2013; Nobel & Roy, 2010).

2.3.2 Flood Defence

Conventional stormwater and flood management approaches use grey infrastructure to contain and control water flow. Grey infrastructure is typically manufactured, concrete structures such as sewer systems, pipes, drains, dams and channels (Office International de l'Eau, 2015). Flood defence infrastructure aims to create distance between the water and the community at risk, working in the following ways: flood protection, flood reduction and flood diversion (UN-Habitat, 2015).

In flood protection, flood water is entirely or mostly impeded from infiltrating an area over an extended period of time, using a constructed system which requires continued maintenance to control flooding in flood-prone areas (UN-Habitat, 2015; Commonwealth of Australia, 2009). Flood protection approaches include reinforcement and establishment of embankments, levees, dikes and by-pass channels to enhance flow rates within drainage channels (UN-Habitat, 2015; Bruzzone, 2012). Measures of flood reduction on the other hand, involve the reduction of water runoff such as the conservation of vegetation, reforestation, sediments and detritus removal from water bodies, preservation of areas situated near water bodies and increasing infiltration (UN-Habitat, 2015). Flood diversion methods assist in rerouting water away from flood-prone areas and flood plains, such as dams, embankments and modifying channels (UN-Habitat, 2015; Ghofrani *et al*., 2016). For example, water sources such as lakes or reservoirs can be fitted with water storage compartments to contain stormwater as part of flood mitigation measures (UN-Habitat, 2015). Similarly, large amounts of water can be contained by dams and released in a controlled manner; however, it should be noted that mismanagement of water release can contribute to dam-release floods in low-lying parts of catchments (UN-Habitat, 2015; Commonwealth of Australia, 2009).

2.3.3 Flood Risk Mitigation

Flood risk mitigation works to reduce the scale or outcomes of flooding by using strategies that are applied within the affected location (Raadgever *et al.*, 2018), such as flood proofing, flood zoning, flood modelling and flood mapping. These strategies which will also vary in application depending on the location, the capacity of resources, the technology available and the policy choices of the authorities. The following sections will provide the functions and effectiveness of these flood risk prevention measures to help understand how they can contribute to managing flood risks.

2.3.3.1 Flood Proofing

Flood proofing works to alleviate the exposure to flood damage by undertaking actions that may supply long-term protection or are employed during emergency flood situations (UN-Habitat, 2015). Flood proofing consists of techniques such as raising the building foundations, creating physical deterrents to prevent floodwaters from making contact with buildings, sealing exterior walls of buildings, designing areas of buildings to permit water flow, transporting goods from flood-prone buildings to safer locations, storing supplies in watertight storage chambers, securing structures and constant maintenance of water networks (UN-Habitat, 2015; The Village of Lumby, 2018). Flood proofing has been used in Vietnam and Bangladesh, in the form of raising houses and facilities, building floating houses, retrofitting houses to allow them to float or storing possessions in upper levels of homes (Zurich Flood Resilience Program, 2020).

2.3.3.2 Flood Zoning

Another flood risk mitigation measure is flood zoning, which is a component of land use planning that estimates the extent and locations of likely floods, and supplies land use rules specific to the flood risks of those areas (Hooper & Duggin, 1996). The establishment of flood zones are typically conducted by the hydraulic and hydrological methods: the hydraulic method involves identifying land types, flooding restrictions and suitable land uses of a floodplain, while the hydrological method is used when the nature of flood behaviours in a floodplain are distinctly delineated (Hooper & Duggin, 1996). The hydraulic method is the more commonly applied approach used around the world, including Australia as it allows the various floodplain zones to be depicted with their respective flood recurrence intervals, which could be 1 in 5-year intervals to 1 in 100-year intervals (Hooper & Duggin, 1996). Local authorities are typically in charge of land use planning and flood zoning of their jurisdictional areas, making it a particularly useful measure as part of flood risk management strategies (Corotis, 2018). However, extreme pressures for land development may result in authorities temporarily prioritising tourism and tax revenues over endeavours to establish flood zones and associated setbacks from flood-prone areas (Corotis, 2018). It is therefore important that authorities recognise that the need to managing flood risk for the long term, employing flood zoning in conjunction with land use planning processes to effectively develop strategies that will assist in increasing future flood resilience.

2.3.3.3 Flood Modelling and Mapping

Modern flood mitigation and management measures are often developed with the help modelling historical flood events of up to at least 100 years in the past to provide information on the location of flood-prone areas, the rate of flood occurrence and scale of flooding (Salathé & Mauger, 2018; UN-Habitat, 2015). Data obtained from modelling is visualised through flood mapping (superimposing the predicted depths of severe floods on location maps) to help with flood planning and zoning (Xue *et al.*, 2018). These measures are used in many countries including New Zealand, Australia and the United States (Hutt City Council, 2020; Brisbane City Council, 2020b; Federal Emergency Management Agency, 2020). Due to the complexities of meteorological systems, modelling methodologies should be downscaled to encompass the climate change impacts on severe weather events and model flood risk responses at a localised community level. (Salathé & Mauger, 2018). The annual exceedance probability (AEP), which is a weather event's likelihood of occurring at a particular scale or greater, can be also ascertained in flood modelling and displayed on flood maps, however the unpredictability of climatic events could result in larger events than initially predicted and planned for (Corotis, 2018).

In locations that bear the brunt of increasing meteorological events as a result of climate change, these modern approaches may not sufficiently account and prepare for the elevated risk and variability of flood behaviours (Salathé & Mauger, 2018). Xue *et al.* (2018) reiterates the need for flood modelling to incorporate revolutionary techniques, such as using both hydraulic and hydrological models to model flood risk. It is crucial therefore, that when planning for floods, vulnerable communities are also pre-empted with historical and future contexts of the flooding situations, which are usually achieved through climate, river and sea level modelling (Salathé & Mauger, 2018). Flood resilience can be improved for communities as the relative risk of flooding in areas are assessed and geographically shown through flood mapping (Xue *et al.*, 2018). However, flood maps need to be regularly assessed and updated to take into account the changing impacts of climate change, so as to maintain robust decision-making and community resilience over the long term (Xue *et al.*, 2018).

2.3.4 Flood Preparation

Flood preparation involves preparing inhabitants so that they are suitably equipped against flood risks. Flood forecasting, warnings, community awareness and education are some such measures. Similar to the other flood risk management strategies mentioned in previous sections, these flood preparation strategies differ depending on the context, indicating that the level of flood preparation that can be provided to the community is dependent on the respective authority's resource and technology capacity.

2.3.4.1 Flood Forecasting and Warnings

Many types of floods can be predicted in advance by monitoring both changing weather patterns and the development of major meteorological events to provide forecasting, preliminary warnings and flood surveillance for the public (UN-Habitat, 2015; Australian Institute of Disaster Resilience, 2009; NFRAG, 2008). Many governments conduct flood forecasting to help the public and businesses prepare in advance of potential floods. Some examples are forecasting centres all throughout Canada that send daily to monthly forecasts and warnings (Government of Canada; 2014) and river flood warnings in Myanmar that are issued 24 to 72 hours in advance with recurring warnings for major floods that are circulated through common telecommunication modes including phones, televisions and radios (UN-Habitat, 2015). Flood forecasting may not be a feasible approach for flood types of a highly variable and sudden nature, such as flash floods, making early evacuation warnings ineffective (UN-Habitat, 2015).

2.3.4.2 Community awareness and education

Implementation of educational programmes and materials are important tools for authorities to increase the knowledge of the public around flood risks. Community awareness of floods involves the provision of information concerning flood risks, provision of information around community and individual flood preparedness, awareness of unsuitable building designs highlighting the methods and warning systems by which communities will be alerted of floods, and mobilising operational and recovery efforts to respond to flooding at a local level (UN-Habitat, 2015; Bureau of Meteorology, 2019; NFRAG, 2008). These measures provide for a higher level of public awareness and integration that are especially important in cases where large-scale relief efforts are delayed in addition to supplementing existing flood mitigation initiatives (UN-Habitat, 2015; NFRAG, 2008). Authorities in flood vulnerable places, such as the United States and Australia have flood awareness websites with targeted information to advise communities of flood warnings systems, evacuation methods and the personal belongings needed (Southeast Metro Stormwater Authority, n.d.; Bureau of Meteorology, 2020). Apart from digital and print means of communication, authorities can engage the community through public meetings, consultations, school initiatives, house visits and evacuation simulations (UN-Habitat, 2015). To provide effective public engagement, authorities should be aware that the public may lack an adequate level of flood and disaster risk awareness and will therefore, have to adapt their engagement methods to suit their communities (Corotis, 2018). Alternatively, community-run projects that harnesses the efforts from volunteers, non-profit community organisations can be helpful in supporting government-led flood mitigation measures, as seen in contexts as diverse as Bangladesh and Brisbane (UN-Habitat, 2015; Action Aid *et al.*, 2013; Oxley Creek Transformation, n.d.). Such projects include creek restoration programmes, riparian planting, clearing sedimentation from water bodies, retrofitting houses, embankment restoration and using flood-resilient agricultural practices (UN-Habitat, 2015).

2.3.5 Flood Recovery

Flood recovery involve practices that help residents to recover from the impacts of floods in addition to improving the robustness and resilience of structures so as to reduce flood risk in future; reconstruction plans, flood insurance and compensation are some examples. Flood recovery strategies likewise are context-dependent, but their effectiveness is also largely influenced by the amount of financial resources available to carry out these strategies.

2.3.5.1 Reconstruction Plans

Flood reconstruction plans help affected residents recover quickly by providing flood-proofing measures to future buildings and facilities, or assisting residents to move to stable, higher or less flood-prone locations (Kundzewicz *et al.*, 2018). Such plans can also provide extensive and dedicated reconstruction efforts to social and economic infrastructure, environmental resources, provide strategies towards managing catchments, watersheds and land use, as well as providing participatory opportunities for public and private sectors in future flood risk management; this is seen in the master plan for rehabilitation and reconstruction of Nanggroe Aceh Darussalam in Indonesia, and the Queensland Reconstruction Authority and local reconstruction plans that were created after the 2011 floods in Queensland (Queensland Reconstruction Authority & World Bank, 2011; Republic of Indonesia, 2005). Additionally, reconstruction efforts are supported with government, private and sometimes foreign funding, which helps to relieve the strain of rebuilding properties and infrastructure from the community and businesses (Queensland Reconstruction Authority & World Bank, 2011).

2.3.5.2 Flood Insurance and Compensation

Flood insurance is a necessary part of the flood recovery process wherein the insurance sector helps to provide monetary support towards reconstructing and repairing properties and facilities damaged by floods and helps the burden of financial costs to be divided up than solely borne by the affected community (Van der Honert & McAneney, 201; NFRAG, 2008; Box *et al.*, 2016). Insurance policies may vary in the types of floods they cover and this will affect the ways in which residents understand insurance coverage and claims, in addition to the level of cover that insurance can support residents in financially undertaking the cost of flood damage (Box *et al.*, 2016; Carter, 2012). It is important that the role of insurance, its applications and their constraints are considered when preparing flood recovery strategies for the community as they highlight a larger issue within public policy around whether insurance should be the responsibility of the state or the individual. This is because residents may find themselves lacking in financial means to afford the premiums required to cover extensive flood damage or may be offered discounted insurance packages that provide a lower level of coverage than realistically needed (NFRAG, 2008). Hence, authorities should consider the ways in which insurance can be structured and administered to ensure that the community is adequately supported when recovering from floods.

Government funding that is allocated for flood recovery are also used to provide compensation in the form of assistance payments, income subsidies and grants for businesses and institutions (Queensland Reconstruction Authority & World Bank, 2011). Flood recovery may be hindered if there are inadequate funds to compensate the public as the wider community will have to bear the financial burden from flood damage (Raadgever *et al*., 2018).

2.4 Frameworks for Flood Risk Management

Noting the broader literature available on the strategies and measures used in managing flood risk, Schanze (2006) suggests that flood risk management should be perceived as a “holistic and continuous societal analysis, assessment and reduction of flood risk” (p. 4), meaning that the flood risk management frameworks are extensive, continuously evaluates risk and employs suitable strategies. Such a risk approach towards flooding would consist of "risk identification; vulnerability identification; avoidance where feasible; designs to reduce vulnerability; and mechanisms for the residual risk such as warnings and emergency response" (Gruntfest & Handmer, 2001, p. 7). This approach takes into account the need for warnings to be issued before the creation of floods, and encompasses the necessity for strategic planning, smarter technology and innovative infrastructure to accommodate increases in water levels and minimise damage (Gruntfest & Handmer, 2001). Utilising a risk-oriented mindset will assist authorities in open-minded and long-term planning towards developing more adaptable flood risk management frameworks that are appropriate for the various social vulnerabilities that can exist within specific contexts. For example, in Bangladesh, marginalised people often live on sand banks and are thus extremely vulnerable to floods, whereas the affluent members of society have more flexibility in choosing more flood-resilient places to live and are able to use flood-robust materials when building their houses (Niel & Roy, 2010).

As floods can have massive social, political, economic and environmental consequences for countries, it is of value to highlight that flood risk management sits within a political-institutional context at the level of government (Raadgever *et al.*, 2018). Countries, even within countries, will vary in the type of flood risk management frameworks and plans that developed, according to the floods they encounter, the historical-cultural mindsets of the people and the political priorities of each government (Raadgever *et al.*, 2018). That is, authorities will adopt any of or combinations of the five flood risk management strategies (as previously described in Table 2.1) to their overall framework as deemed relevant by the planning and policy landscape, which is in itself determined by their political-governance environment. For example, Belgium generally places a heavy focus on flood risk prevention and flood defence strategies, but has recently implemented flood mitigation measures, however different measures were employed within those strategies due to the different planning and policy frameworks created by Belgium's three administrative divisions (Raadgever *et al.*, 2018). On the other hand, Netherlands have historically used flood protection for building in flood-prone areas but have more recently prioritised flood risk mitigation and preparation strategies (Raadgever *et al.*, 2018).

It is seen through the wider literature, that countries and organisations may also interchange structural and non-structural approaches amongst different flood risk management strategies, but all culminate in the overarching goal of managing, decreasing or restricting flood risk. Accordingly, frameworks on flood risk management vary in the way the risks and responsibilities are delegated to respective authorities. For example, local and regional authorities are in charge of handling local flood risks and the associated management, while state or central government might be responsible for wide-scale forecasting and mapping, delegating of powers for local authorities, agency partnerships, flood recovery works, providing funding for flood recovery and disaster research (Ministry of Environment, 2008; Alexander *et al*., 2016). Thus, flood risk management and its frameworks can be understood as an arena of decision-making amongst various vested participants, that interacts with the "political, administrative, planning and cultural systems" (Schanze, 2006, p. 5) to create processes to suitably handle and diminish flood risks.

Mees *et al.* (2014) highlights that the designation of responsibilities can trigger challenges around authority and power wherein some participants may have their interests represented more than others. For example, Helsinki and Hamburg demonstrated distinctions in public and private responsibilities whereas Rotterdam had significant levels of public-private duties. However, decision-making around flood risks in all three cities faced some challenges from both public and private interests, with Rotterdam experiencing conflicts around the designation of responsibilities and flood adaptation strategies used (Mees *et al.*, 2014). Moreover, responsibilities and policies in flood risk management may be at loggerheads with other governance concerns such as, socio-economic growth and the development of infrastructure and housing (Butler & Pidgeon, 2011). This was observed by Butler & Pidgeon (2011), who found that in the United Kingdom, agencies have varied responsibilities and lack an overarching integrated approach resulting in an emphasis on accountability for floods over applications of how responsibilities can be reimagined to effect more sustainable flood risk management approaches. The next section will go through the increasing inclusion of blue and green infrastructure in managing water and to support grey infrastructure in flood risk management.

2.5 Blue-Green Infrastructure and Flood Risk Management

Urban areas and cities are made up of natural (blue and green) and man-made (grey) components, which impact on the residents' well-being and urban forms (Ahmed *et al*., 2019). As such, Ahmed *et al*. (2019) note that "over densification and unplanned urbanisation leave little room for interaction among blue, green and grey elements" (p. 1), resulting in a lack of importance placed on natural features such as greenery, land features and water. Grey infrastructure is the conventional infrastructure used within flood management and mitigation, however research notes that grey infrastructure contributes to urban environmental stress, lacks sustainability and faces increasing pressures from expanding populations and climate change (Ahmed *et al*., 2019; Alves *et al.*, 2019). With the increasing frequency, duration and severity of flood events, especially due to climate change, there is a growing body of research that highlights the rigidity of traditional grey infrastructure (Ahmed *et al*., 2019; Alves *et al.*, 2019), which indicates the need for more sustainable and adaptable infrastructure and practices to manage stormwater and floods over the long-term.

2.5.1 Blue-green Infrastructure

The challenges brought upon by climate change, volatile weather patterns and increasing urban growth highlight the need for urban water systems to utilise more sustainable and robust approaches (Wong & Brown, 2009). Water sensitive cities and integrated urban water management (IUWM) are broad concepts that aim for wider applications of sustainable water management, necessitating the restructuring of urban water management systems which can be difficult to achieve (Wong & Brown, 2009; Fletcher *et al.*, 2015). Water sensitive cities are the manifestation of city-wide implementations of water sensitive urban design (WSUD) and aims for urban water sustainability (Wong & Brown, 2009). In contrast, IUWM integrates the management of all water processes in a sustainable manner and includes the functions and actions of stakeholders to facilitate multiple purposes in urban water utilities to maximise their sustainable results (Fletcher *et al.*, 2015; Mitchell, 2006). Instead, these wider concepts have led to the evolution of more adaptable water and urban drainage management approaches: WSUD in Australia and New Zealand, sustainable urban drainage systems (SUDS) in the United Kingdom, low impact development (LID) in North America and New Zealand, and best management practices (BMPs) in the Canada and the United States (Wellington City Council, n.d.; Voskamp & Van de Ven, 2015; Drosou *et al.*, 2019; Fletcher *et al.*, 2015).

Blue-Green Infrastructure (BGI) is a concept developed from WUSD that uses natural components associated with water and natural drainage systems (blue), land and vegetation systems (green) and natural engineering technology to construct man-made infrastructure

(Alves *et al*., 2019; Lawson *et al.*, 2014; Drousou *et al.*, 2019; Ahmed *et al.*, 2019). BGI comprises measures that uses natural ecosystems, its processes and features to provide multi-functional benefits to urban and natural environments, public health, air quality, water quality, flood control, water storage, decrease in urban heat island effect, biodiversity, urban amenity and environment sustainability over the long-term (Office International de l'Eau, 2017; Ghofrani *et al.*, 2016; Drousou *et al.*, 2019; Lawson *et al.*, 2014; Wellington City Council, n.d., Everett *et al.*, 2018). The role that BGI plays within the water management can be best understood as utilising natural and manufactured elements to re-establish ecosystems or their natural processes so as to assist in managing water similar to the way hydrological patterns would operate in nature, as explained by Office International de l'Eau (2017).

Within this research, I will consider the various water and urban drainage management approaches (WSUD, SUDS, LID, BMPs) as types of Blue-Green Infrastructure for the following reasons as based on literature by Fletcher *et al.* (2015) and Dousou *et al.* (2019): Firstly, these urban water and drainage management concepts have minor differences but largely share conceptual similarities amongst each other. Secondly, these concepts are sometimes used interchangeably with the concept of Blue-Green Infrastructure (BGI). Lastly, all of these concepts including BGI, work towards greater holistic water and urban drainage management, also known as IUWM.

Many countries have adopted and implemented BGI strategies, such as Australia (Wong & Brown, 2009); Singapore (Public Utilities Board, 2016), the Sponge Cities of China (Wang *et al.*, 2018), Netherlands (Alves *et al*., 2019), Flanders in Belgium (Flanders Land Agency, n.d.), the naturalisation of Oakley Creek, Auckland (Auckland City Council, n.d.) and green stormwater management in Portland, United States (Thorne *et al.,* 2018). In particular, Melbourne's adoption of BGI in the form of WSUD is well known as a best practice in enhancing the city's stormwater management and the health of waterbodies (Wong & Brown, 2009). Singapore, the secondary case study of this research has adapted Melbourne's WSUD practices to develop its own holistic integrated approach to stormwater and flood risk management, this will be described in further detail in Chapter 5 (Singapore Context). The multifunctionality of BGI demonstrates its adaptability to different urban and natural contexts, works and is acknowledged to be a more sustainable form of managing stormwater and flood risk management (Drousou *et al.,* 2019).

2.5.2 Blue-Green Infrastructure in Flood Risk Management

Noting that BGI can assist in rebuilding, preserving and regulating natural hydrological processes such as infiltration, runoff and purification, it is important to recognise BGI's applications within flood risk management (Drousou *et al.,* 2019; Office International de l'Eau, 2017). This would involve increasing permeability and infiltration, replicating natural hydrological patterns, restoring natural waterways, enhancing water quality and relieving pressure from stormwater management networks (Lawson *et al.,* 2014). Examples of BGI approaches (Drousou *et al.,* 2019; Flemish Land Agency, n.d.; Auckland City Council, 2019; Lawson *et al.,* 2014) are listed in Table 2.2 below.

Table 2.2 *Examples of Blue-Green Infrastructure*

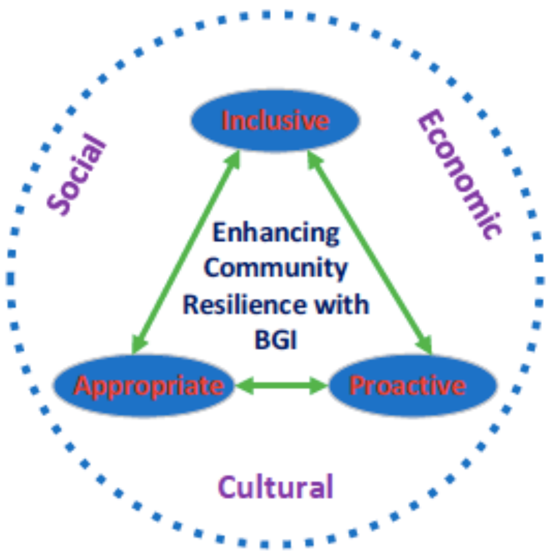
Blue-Green Infrastructure		
Infiltration wells	Retention ponds	Permeable pavements
Biopores	Bio-swales	Rain gardens
Green roofs	Rainwater harvesting systems	Green walls
Bushes/Plants	Woodlands	Grasslands
Green spaces/Parks	Artificial buffer basins	Creek/River Restorations
Trees/ Urban forests	Wetlands	Pond systems
Green corridors	Waterways	Green Parking

Note. Examples of Blue-Green Infrastructure applications (inclusive but not exhaustive list).

BGI can be applied across various spatial scales, making it a highly-adaptable strategy to employ for water and flood risk management. Small-scale BGI works to improve ground infiltration and reduce runoff across urban surfaces, such as permeable pavements, green roofs, downspout disconnections (Office International de l'Eau, 2017; Environmental Protection Agency, 2020). BGI applied at the scale of large urban areas or cityscapes can work in tandem with drainage networks and other grey infrastructure to increase their effectiveness by assisting with infiltration, water storage and the restoration of ecosystems and biodiversity (Office International de l'Eau, 2015; 2017; Drousou *et al.*, 2019; Thorne *et al.*, 2018). Regional scale BGI can involve managing land use to support the conservation of land, the preservation of water bodies and riparian vegetation that naturally aid in water storage and will help to reduce overall flood risk (Office International de l'Eau, 2017; Ghofrani *et al.*, 2016).

The usage of BGI in water and flood risk management can thus illustrate a "conceptual shift from conventional approaches" (Ahmed *et al.*, 2019, p. 3) within planning processes, employing natural infrastructure as "resilient and adaptive measures" (Lawson *et al.*, 2014, p. 115) that can be cost effective over the long run if planned strategically (Ghofrani *et al.*, 2016). The growing global uptake of BGI is not without its barriers: the lack of knowledge about BGI, minimal or absence of BGI application in planning systems and strategies, urban space constraints, and scepticism against its value, adaptability and applications (Drousou *et al.*, 2016; Ahmed *et al.*, 2019; Lawson *et al.,* 2014). Several community-oriented criteria are recommended for BGI to be effective within flood risk management: inclusivity through public participation, proactive diverse stakeholder engagement and context-suited application (Drousou *et al.*, 2019; Staddon *et al.*, 2018); this is visualised in Figure 2.2 below.

Figure 2.2 *Representation of A Community-centred Approach to Enhancing Flood Resilience with Blue-Green Infrastructure.*



Note. Visualisation of criteria needed within flood risk management for effective Blue-Green Infrastructure integration (image source: Drousou *et al.*, 2019).

Inclusive public participation aims to encompass all inhabitants facing flood risks, regardless of their socio-economic or cultural demographics, in public participation (Drousou *et al.,* 2019;

Staddon *et al.*, 2018). Secondly, the engagement of diverse stakeholders (the public, water professionals and policymakers) also requires their initiative and joint efforts in "the planning, development and maintenance stages" of BGI integration (Drousou *et al.,* 2019, p. 2). Lastly, BGI approaches should be relevant, practical and financially reasonable to the local conditions, taking into account the associated social, cultural and economic circumstances of the areas (Drousou *et al.,* 2019; Staddon *et al.,* 2018). Policies and strategies created with such criteria in mind can support the integration of BGI into flood risk management systems, not only at the governance level, but also allow communities to appreciate and be involved in its implementation (Drousou *et al.,* 2019). The next section will then introduce two international examples of BGI initiatives and identify their respective strengths and weaknesses, which will provide perspective to the adaptability of BGI.

2.5.3 Cheonggyecheon Restoration Project

The Cheonggyecheon Restoration Project is an example of site-specific BGI implementation aimed at revitalisation and provide diverse benefits including flood risk management. The Cheonggyecheon stream in Seoul, South Korea, underwent an extensive restoration project from 2003 to 2005 that transformed it from a derelict stream that was enclosed in concrete and topped with a raised highway, into a healthy waterway and green corridor (Landscape Architecture Foundation, n.d.; Commission for Architecture and the Built Environment, 2011). Despite public criticism, the Seoul Metropolitan Government offered financial incentives to businesses in addition to stakeholder and community consultations that demonstrated the beneficial outcomes offered by the Cheonggyecheon's restoration (Development Asia, 2016). The project resulted in the reestablishment of nature within Seoul using BGI-centric urban designs, provided a boost for the economy, reinstated the historical and cultural memory of the stream and its surrounding area and became a popular recreational asset (Landscape Architecture Foundation; n.d.; Development Asia, 2016). The environmental outcomes that was expected to arise from the restoration were: flood protection for a flood with a 200-year recurrence interval, elevation in biodiversity levels, reduction in urban heat island effect and a decrease in particle pollution (Landscape Architecture Foundation, n.d.).

The project to an extent kickstarted changes in South Korea's planning landscape from an urbanisation-centric mindset to more priority placed on environmental revitalisation, the public's needs and overall sustainability (Landscape Architecture Foundation, n.d.; Commission for Architecture and the Built Environment, 2011). However, the project was argued to have its limitations as it exceeded its budget, contributed to gentrification of its neighbouring areas and did not accomplish full restoration (Lee & Anderson, 2013). Indeed, Lee and Anderson (2013) see this as a reinterpretation of the stream's environment and history rather than a restoration per se. Cheonggyecheon demonstrates the importance for waterways to be recognised and integrated into the cityscape and the positive benefits that BGI can bring, however its lessons show that authorities need to understand the principles of BGI, and have the political will to thoroughly contemplate and plan for its implementation and maintenance over the long-term.

2.5.4 China's Sponge Cities

Following on from the site-specific example in South Korea, a large-scale application of BGI can be seen within the sponge cities of China. Modifications in land use, evolving socio-economic conditions, and periods of extreme rainfall, many cities in China face flooding issues (Chan *et al*., 2018; Shao *et al.,* 2016). China's water and flood risk management have primarily used grey infrastructure and structural approaches as municipal water engineers typically oversee these sectors (Chan *et al*., 2018). The 'Sponge City' concept, was developed by China as a national government initiative and trialled in 30 large cities since 2014, in a bid to decrease environmental harm, attenuate flooding, enhance water quality and runoff purification, re-establish the infiltration processes of water bodies and water storage, and ameliorate cities' microclimates (Chan *et al*., 2018; Wang *et al*., 2018; Shao *et al*., 2016). The 'Sponge City' programme builds upon LID principles and global best practices of BGI to create an IUWM strategy suited to China's local context that assists in managing peak runoff, filtering and storing of stormwater, improving the robustness of flood risk management infrastructure, integrating natural water systems into urban drainage, providing ecosystem services and constructing more green spaces (Wang *et al*., 2018; Chan *et al*., 2018; Shao *et al*., 2016; Xia *et al*., 2017).

The creation of a sponge city necessitates the careful deliberation of natural water cycles, constructed water networks including development and land use (Shao *et al.*, 2016). Moreover, the sponge city strategy functions on the following theories: adaptive resilience of the city's infrastructure to nature using a combination of grey and BGI, "systematic and comprehensive" (p. 321) integration of approaches to tackle water issues, and the priority placed upon restoring, conserving and mimicking natural hydrological patterns in the environment (Wang *et al.*, 2018).

Despite the clear potential of sponge cities, other authors suggest they are not without their challenges. For example, Sponge cities may experiences difficulties with the high investment needed for building and the uncertainty of climate change effects on BGI (Wang *et al.*, 2018). One might also assume that the vast scale of these sponge cities may lend itself to complications in the planning processes. It is evident that the collaboration of various government divisions such as urban planning, water, transport and parks, is needed to successfully integrate the concept into the existing complex urban fabric of China's cities (Shao *et al.*, 2016) along with an overarching strategic plan integrating and addressing all of the water issues (Xia *et al*., 2017). Nonetheless, this innovative concept in China's urban planning allows its policies and regulations to create opportunities for the consideration of environmental and urban sustainability and the coordination of water and flood risk management with urban planning (Chan *et al.*, 2018; Xia *et al.*, 2017). China's sponge cities demonstrate that an integration of resources across various levels of government, a shared vision, careful planning on the design, investment and maintenance costs, and continuous research is required for the effective delivery of large-scale BGI applications within a IUWM strategy.

2.6 Conclusion

Through the literature review, it can be seen that flooding is a highly variable hazard event that occurs based on a variety of factors from geographical and meteorological elements to increasing pressures from urban development and climate change. The consequences from floods can also be highly devastating, therefore places and communities at risk of floods should employ flood management and mitigation measures. It is important to highlight that flood risk management should not solely rely on structural methods for mitigation of flood risks due to their individual limitations but should also implement non-structural methods which encompass pre-emptive actions that will improve mitigation responses. Using a combination of structural and non-structural approaches adapted to suit flood-prone locations and the nature of floods experienced will help authorities in ensuring that the risks can be reduced, and affected communities will be able to deal with flood events more effectively.

Flood risk management would benefit from the deliberation and inclusion of BGI measures alongside conventional grey infrastructure to not only work towards an integrated approach to water management, but to also learn from natural systems on ways to provide solutions to urban issues and multiple benefits to enhance urban and environmental sustainability. The example of Seoul demonstrates that although fiscal capacity is important to the implementation of BGI, it is crucial that governments understand the principles of BGI and carefully plan for full implementation of BGI for its potential to be maximised even in a more site-specific context. In contrast, the more recent approaches in China show that resource integration across government sectors, dedicated planning and investment and constant research to identify areas of improvement are important to the implementation of large-scale BGI initiatives. Hence, it would also be of benefit to look towards international examples to learn from and develop BGI strategies that would adapt and integrate well into different flood risk management and planning frameworks.

3 Methodology

3.1 Introduction

This chapter introduces the research approach used within this study to conduct this research. An important part of the research was in collecting primary and secondary data using a variety of methods. This greatly enriched the research as it helped to gain different perspectives on the comparative experience of flood risk planning and management in Brisbane and Singapore. Undertaking research in this manner has clear advantages but it also carries significant challenges. Section 3.2 details the research approach used and the corresponding justifications. Section 3.3 provides an overview of the research methods used to obtain data. An overview of the primary and secondary research methods to acquire the data are discussed in section 3.4 and 3.5. The following section 3.6 expands upon the methods used to analyse the data collected. Lastly, the ethical considerations and positionality undertaken for this research will be discussed.

3.2 Research Approach

A social constructivism research approach is chosen for this research as it allows a diverse range of subjective interpretations to be generated and expanded upon so as to better perceive the significance of the chosen topic (Creswell, 2013). The perceptions of individuals are influenced by their social actions with other individuals along with their cultural and past principles and behaviours (Creswell, 2013). This research looks not only to assess flood risk management strategies in Brisbane, but also to explore the potential for Blue-Green Infrastructure (BGI) to be implemented alongside current strategies used in Brisbane's flood risk management. To help provide further insights on Brisbane's flood risk management strategies and BGI applications, a comparison to Singapore's approach will also be undertaken. The social constructivist approach is important to this research as it highlights the local, historical and social context within which flood risk management occurs, and the systems of interactions that shape planning for flood risk management. The meanings that I obtain from utilising this approach will assist in a better understanding of how flood risk management and BGI is perceived through the local lens. This is particularly because the views and beliefs of the interviewees will elucidate the various power dynamics and interests that influence the decision-making and types of strategies used when planning for flood risks.

3.3 Research Methods

It was shown through the literature review that flood risk management and blue-green infrastructure is best understood within the geographical-historical context of the flood-prone location, political-governance landscape and community involvement. A case study approach using qualitative research methods was determined to be suitable for this thesis as it would provide the basis for which to understand the intricacy of these topics and their relationships, in addition to generating learning opportunities (MacCallum *et al.*, 2019). Semi-structured interviews with key informants were used as the primary research method with which to obtain data about Brisbane and Singapore. This was followed by secondary research methods comprising of a literature review, an analysis of the policy and planning documents, government flood maps and images around flood risk management, and BGI. Using both primary and secondary research methods allowed the relationship between flood risk management and BGI to be assessed in detail, particularly within the context of planning and policy in Brisbane and Singapore.

3.3.1 Case Study Approach

This research uses the case study research as its qualitative research approach. A case study approach explores a case that is selected in relation to specific boundaries, such as a particular time period and environment (Yin, 2017; Creswell, 2013). This approach uses various sources of data to build up a comprehensive understanding to allow the researcher to glean a multiplicity of perspectives and specific details around a chosen event within its situational, real-world context (Creswell, 2013; MacCallum *et al.*, 2019; Yin 2003). Flood risk management practices are affected by geographical, historical, political, social and economic circumstances. These circumstances also affect the ways in which BGI, which is seen as a modern approach in flood risk management, is implemented. Therefore, a case study approach was chosen to help to build an in-depth, contextual understanding of these roles and relationships. This research uses a dual case study approach to investigate current flood risk management practices and how the inclusion of BGI can help to innovate such practices and improve the sustainability of flood-prone areas.

Brisbane, Australia was chosen as the primary case study to understand its current flood risk management strategies after the 2011 Brisbane floods, the current level of BGI implemented and the opportunities available within these strategies to further promote BGI use. For the secondary case study, Singapore was selected as it has been recognised as a best-practice example of an integrated stormwater management approach that uses BGI to support flood risk management in addition to the smooth integration of BGI into an urban cityscape. Brisbane and Singapore are both highly urbanised cities with riverine catchments that face exponentially growing populations. Although Brisbane has a sub-tropical climate that experiences contrasting weather events, while Singapore has a tropical climate with monsoonal seasons, both locations share similarities where they experience high rainfalls and high winds which in addition to being close to seas, puts them at risk for flooding. Acknowledging the adaptability of BGI, Singapore's strategy of BGI implementation can offer learning opportunities to a different flood-prone site and context like Brisbane. An overview of the methods used to obtain data in both case study locations are shown in Table 3.1.

Table 3.1 Data Collection Methods.

Qualitative Research Approach	Specific Methods Used
Primary case Study – Brisbane	Interviews, policy and strategic planning documents, visual materials
Secondary case Study – Singapore	Interviews, policy and strategic planning documents, visual materials

Note. Data collection methods used for the Brisbane and Singapore case studies.

3.3.2 Semi-structured Interviews

Primary research data was obtained through online semi-structured interviews of key informants who were knowledgeable of or had previously worked in the case study locations. Semi-structured interviews are often used within land use planning and urban design research where a portion of questions are pre-designed, allowing the researcher to guide the conversation focus and to obtain the information specific to the research (Steven, 2018). This interview style also allows the researcher to introduce other relevant questions that were not part of the original format and discover further information (Steven, 2018). Moreover, this style also provides for a more casual environment that allows the interviewee to a degree of flexibility to openly discuss their perspectives (MacCallum *et al.*, 2019). Hence, semi-structured interviews were chosen as a suitable method to assess the current flood risk management strategies and the level of BGI currently utilised in flood mitigation, as it would offer valuable local perspectives from key informants. This enables participants to provide intuitive viewpoints from their expertise and experiences (DeLyser and Sui, 2014).

The primary research was initially intended to be conducted in the study locations however, local travel restrictions arising from the COVID-19 pandemic prevented any overseas travel for data collection. Hence, it was determined that conducting the semi-structured interviews online would be the most feasible option. Interviews with key informants were then undertaken through online video conferencing applications, namely Zoom, Skype and Microsoft Teams. Interview questions revolved around the topics of the 2011 Brisbane Floods, policy and decision-making process, the governance landscape, flood risk management, planning and policies, community and stakeholder involvement, and BGI implementation. The semi-structured interviews used open-ended questions to extract further information and enabled participants to respond naturally and expand upon their viewpoints (Steven, 2018). Probing questions were also subsequently used to acquire further details in relation to the participant's earlier response, elucidate earlier points and to redirect the interviewee back to the topic at hand (Steven, 2018; Stanton & Young, 1999; MacCallum *et al*., 2019).

Interview participants were selected based on their expert knowledge in stormwater or flood management, climate change adaptation, disaster risk, flood planning and policy, blue-green infrastructure and public and stakeholder participation. These participants were recruited through expert sampling, and snowball sampling techniques (MacCallum *et al.*, 2019; Magnusson & Marecek, 2015). The expert sampling technique involved directly contacting participants through public websites. After interviewing these informants, the snowball sampling technique was used to acquire further contacts (MacCallum *et al.,* 2019; Magnusson & Marecek, 2015) who had targeted expertise related to my research. The snowball sampling method was especially beneficial as the rapport that I had built with the interviewed participants meant that they often suggested contacts of other experts or introduced me to them.

Primary research was conducted through individual semi-structured interviews with 14 key informants. Participants were categorised into three classifications based on their job scopes: academics, consultants and Brisbane City Council (BCC) staff. 10 participants were interviewed on Brisbane's flood risk management. Four participants were interviewed on Singapore's flood risk management and BGI; these key informants were aware that my primary case study is Brisbane and that I was asking for their experiences on Singapore to glean lessons for Brisbane. These participants had contextual knowledge of Brisbane and while they spoke about Singapore, they also made frequent references to Brisbane. In contrast, the informants for Brisbane did not make references to Singapore.

To maintain anonymity, interviewees will be referred to by codes: academics (A1 – A9), consultants (C1 – C3) and BCC staff (B1 – B2); this is shown in Table 3.2.

Table 3.2 List of Interview Informants.

Key Informant	Academics (A)	Consultants (C)	Brisbane City Council Staff (B)
1	Associate Professor – Climate Adaptation Science	Landscape Architect	Councillor
2	Academic – Climate Change Response	Climate Change Adaptation Specialist	Flood Policy and Planning Engineer
3	Associate Professor – Environmental Psychology	Water Management and Engagement Specialist	
4	Academic – Environmental Politics and Policy		
5	Historian and Academic		
6	Academic – Urban Water Management and Policy		
7	Academic – Hydrology		
8	Professor and Geomorphologist		
9	Assistant Professor and Civil and Environmental Engineer		

Note. List of interview informants and their general area of expertise.

There were challenges that arose with the methods of recruitment, where the expert sampling technique used to recruit participants through websites often yielded no responses or responded later than expected. Within the potential participants that responded, I found that a number of them did not have an area of expertise that was related to my research whilst some of them responded only after the intended fieldwork timeframe. Similarly, snowball sampling experienced similar challenges of potential participants not responding, responding late or had an area of expertise that was less related to my research. This was the situation with government staff as specific contacts could only be acquired through referral. Some potential participants were reluctant to speak to me in a professional capacity. Indeed, although potential participants were assured of confidentiality, some of them were not confident in the level of anonymity that will be afforded to them in the research and decided not to participate, instead referring me to online sources of information; this was the case for some Brisbane and Singapore government staff. Despite these challenges overall both methods of recruitment were still quite successful as they gathered a substantial number of informants that offered valuable views to both case studies.

3.3.3 Data Analysis

Data analysis was initiated by transcribing the audio recordings of the interviews conducted. An inductive thematic approach to analysis was applied (MacCallum *et al*. 2019) by coding the data into broad themes and minor themes. Coding is a strategy that helps to derive concepts, wherein common aspects are identified amongst data to highlight major themes discussed in the interviews (Flick, 2018). Through coding, categories are determined by identifying data that are similar or different to each other which then allows the bundling of data in their respective categories for comparison (Flick, 2018). This also allows further concepts to unfold through "contiguity-based relations" (Flick, 2018, p.22), wherein these concepts can manifest through the establishment of abstract notions after data has been classified (Flick, 2018). Along with the transcripts, I had a document of notable concepts and perspectives that were discussed from the interviews. This helped to streamline and support the key themes identified through transcription in addition to the perceptions that the informants had towards the current flood risk management and planning landscape and BGI use. The themes that arose from the coding subsequently contributed to the results following the document analysis.

3.3.4 Secondary Research

Secondary research was conducted using government strategies and policy documents, government websites and academic literature that was involved in managing and mitigating flood risk and implementing BGI. Data was obtained from academic and grey sources of literature to not only inform the research questions but to also build an overarching perspective of the challenges that the variable nature of floods presents to flood risk management and mitigation and the wide array of approaches that are used to address this hazard. Moreover, the literature review provided a necessary foundation to understanding the institutional context which flood risk management is situated within and the ways in which BGI can be integrated into existing flood risk practices. Secondary data was also obtained from an analysis of policy documents and approaches, government maps and images around the current flood risk management strategies in Brisbane and Singapore; these are presented as results in Chapters 6 and 7.

In Chapter 6, each policy, plan and approach used in Brisbane in relation to flood risk management and BGI were outlined through a document analysis and their most significant contributions were encapsulated in a brief summary. This assessment also done for Singapore in Chapter 7, in addition to scoring schemes comparing the approaches used for Brisbane and Singapore where only the components in the documents that were pertinent to flood risk management and BGI were analysed. Derived from the literature review, the scoring schemes' criteria contain five general flood risk management strategies (shown in Figure 3.3) and six core areas of BGI that are key to the infrastructure's successful implementation (the approach will be described in detail in Chapter 7). Briefly, these six core areas of BGI are:

A. Planning for a range of BGI measures;
B. Optimisation of BGI at various scales to support structural and non-structural approaches in flood risk management strategies;
C. Harnessing BGI's adaptability for a multiplicity of value-added functions;
D. Public participation;
E. Stakeholder engagement and collaboration;
F. Practicable and context specific application

The analysis was done by scoring the relative attributes in both case studies regarding flood risk management and BGI implementation. In doing so, Chapter 7 provides a summary assessment of how effective these policies were for managing flood risks and administering BGI according to the criteria described. Examples of the scoring scheme criteria are shown in Figure 3.3 and 3.4 below, with the full schemes shown in Chapter 7.

Table 3.3 *Example of Scoring Scheme to Assess Flood Risk Management.*

Documents	Flood Risk Management Strategies				
	Flood Risk Prevention	Flood Defence	Flood Risk Mitigation	Flood Preparation	Flood Recovery

Figure 3.3. Example of the scoring scheme in Chapter 7 used to assess flood risk management strategies.

Table 3.4 *Example of Scoring Scheme to Assess BGI Implementation.*

Planning and Policy Document	Criteria						Total score
	A	B	C	D	E	F	

Note. Example of the scoring scheme in Chapter 7 used to assess the level of Blue-Green Infrastructure implementation.

Using the document analysis and the scoring schemes were important as they provided an overview of the rationale of the policies and strategies for flood risk management along with the level of BGI applications used towards addressing flood risks in Brisbane and Singapore. Additionally, the scoring scheme was useful in identifying gaps and areas of improvement for Brisbane through the comparison with Singapore.

3.4 Ethical Considerations

Conducting research in the field of planning involves ethical considerations whereby it is necessary to carefully manoeuvre amongst and take into account the different concerns and stakes of the stakeholder groups involved, including the beliefs of the researcher (MacCallum *et al*. 2019). It is essential to ensure the confidentiality of participants as part of ethical research, where the harm, risks and benefits are considered (Magnusson & Marecek, 2015; MacCallum *et al*. 2019) The semi-structured interviews conducted in this research involved open-ended discussions that may have elicited personal information and memories of floods which could have been traumatic to participants who have experienced them. Participants were informed of the option to preserve their anonymity through information and consent forms and all efforts were sought to remove any identifying details that might have been disclosed during discussions. To reduce the risk of harm to participants, they were assured through the information and consent forms that the data collected is within the overall context of the research topic and that transcripts could be requested for review if needed. Confidentiality is further maintained by using the codes assigned to participants when referring to data used within this research.

To undertake field research via virtual means, a University of Otago Ethics A application was submitted and approved by the University of Otago Human Ethics Committee. This is to ensure that any ethical issues would be avoided in this research. The Ethics A application detailed the research aim and questions, the recruitment of the participants, the method of data collection and the data used within results. All participants provided written consent before the interviews and were informed of their right to withdraw from the research at any point. The information sheet and consent form regarding data collection that was provided to the interview participants is attached within the Appendix A and B.

3.5 Positionality

Positionality is an important component of research where a researcher's background, their social perceptions and their worldview can shape the way the research designed, the manner in which data is collected, their interactions with interview participants and meanings inferred from the data (Creswell, 2013). My positionality within this research comes from my background as a Singaporean female of mixed descent studying overseas as an international student in New Zealand. Although I have travelled overseas throughout my life, I have not been to Brisbane; the closest experiences I have had in Australia are of Sydney and Perth. I can only rely on those experiences, and my general knowledge and literature to provide me with an overarching view of the environmental, cultural, social and political landscapes in Brisbane. I have also never lived through floods as immense and destructive as the 2011 Brisbane floods. Therefore, it is important to acknowledge the knowledge gap that I may have around Brisbane as an external researcher, but also that I may be able to offer insights from an alternative and impartial perspective.

I have, on the other hand, lived most of my life in Singapore, which makes me privy to intimate understandings of the culture, governance, urban development, politics and issues, allowing me to have both broad and detailed perspectives of the Singaporean experience. Moreover, my personal knowledge of Singapore has enabled me to better connect with the three informants who are informed about Singapore and understand their views about the local context during the interviews. The differences in my experiences allowed me to treat all of the research participants affably and equally and allowed the participants to discuss their knowledge and opinions in an open manner. It should also be recognised that depending on their occupation, participants may present views that are favourable, not favourable or neutral around flood risk management and BGI. Regardless of their perspectives, participants were put at ease during the interviews with semi-structured questions, were given the option to be anonymised and the opportunity to review the interview transcripts to ensure that their views were depicted precisely.

3.6 Limitations

There were several significant limitations of this research, much of which was because of the global pandemic of COVID-19 that occurred during the period in which research was anticipated to be conducted. The inability to travel to the study locations to conduct face-to-face semi-structured interviews with key informants was a significant limitation. Conducting interviews in person would have provided the opportunity to better acquaint myself with my interview participants and facilitate a more comfortable interviewing environment. Observation of participants can be conducted during interviews, providing data around the participants' attitudes within their activity setting (Steven, 2018). Although conducting online interviews reduced the opportunity to directly observe participants within their environments as they discussed their perspectives, it did not hinder observations overall. Online interviews still provided the opportunity to connect with experts (who were all working from home) in an informal setting and at their convenience. The participants especially understood the challenges of having to conduct research online due to the travel restrictions and provided detailed and beneficial perspectives around both case studies.

The inability to travel to the study locations also meant that I was unable to directly observe the existing settings of the study locations and the physical implementations of flood risk management measures and BGI projects. Observations of the study locations allow data to be obtained in active and intricate environments of the activity setting (Steven, 2018), which would offer a perceptive look into the existing circumstances. However, this limitation is managed through obtaining information from official planning documents, community websites and maps.

A larger sample size of BCC professionals was desired for this research to obtain more variety in views around the BCC's planning processes around flood risk management and the strategies used within. However, the BCC informants obtained for this research still offered important insights to the priorities and experiences around how the BCC conducts flood risk management and BGI. More informants from the BCC would be useful for future research to gather a wider range of perspectives that would be more representative of the different areas that contribute to the planning of flood risk management and BGI in Brisbane.

Another limitation was the lack of key informants from government agencies in Singapore due to the COVID-19 measures in place, and confidentiality issues with using video conferencing applications to conduct interviews. Perspectives from Singaporean government staff may provide a more in-depth understanding to their motivations, priorities and experiences that have enabled effective planning and maintenance of their flood risk management and BGI approaches. Future research would be beneficial to better understand Singapore's local planning processes undertaken within flood risk management and BGI which could provide future learning opportunities in other countries.

Overall, the approach and methods I have taken for this thesis has shown me considerable insights about the existing literature around flood risk management and BGI in general and the policies used in Brisbane and Singapore as well as the core insights gained about the effectiveness, issues and the areas of improvement through the key informant interviews. To delve further into the specifics of the case studies, the thesis now turns to a detailed description of primary case study Brisbane, addressing its geography and climate, flood history, flood types, urban planning and governance approaches.

4 The Brisbane Context

Brisbane was chosen as the primary case study for this research as it is a highly dense urban city that often experiences flooding due to its climate, geographic location on a floodplain and the pressures from growing urbanisation and changing land use. This case study is of interest to see identify how its flood risk management can be improved and how Blue-Green Infrastructure (BGI) can assist in mitigating flood risks.

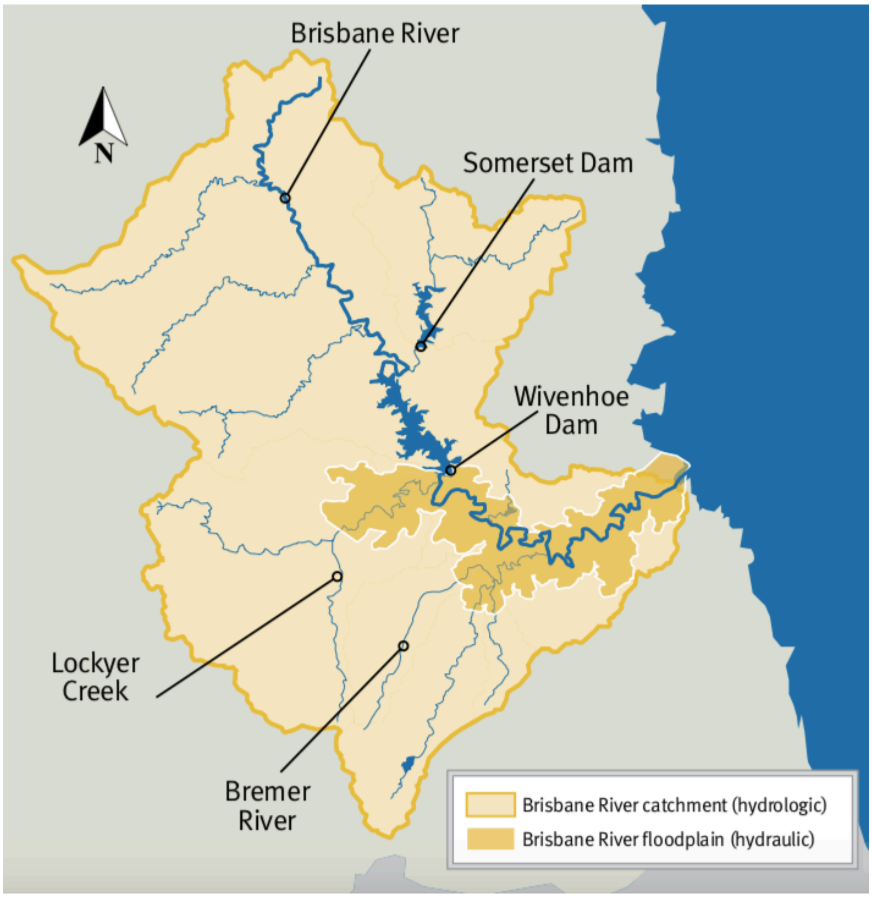
The chapter begins with an examination of the geographical context of South East Queensland (SEQ) and Brisbane noting the continuing significance of flood events for the region. It then moves more specifically to examine the history of floods within Brisbane noting that large floods within the city that have often caused considerable damage to property and impacts upon on the broader physical environment. A particular focus is on the 2011 floods, as it is argued that Brisbane's approach to flooding changed significantly after this time. Brisbane experiences several different types of flood events which come from different sources. As a consequence, the next part of the chapter examines how we might categorise and understand these different types of floods before then turning to an examination of the governance and planning challenges that they present. The chapter concludes this examination of governance and planning by demonstrating the complexity of governing Southeast Queensland and Brisbane through the Brisbane City Council (BCC).

4.1 Climate and Geography of South East Queensland and Brisbane

Located in a subtropical river basin, the region of South East Queensland comprises extensive floodplains, mountain ridges and river catchments (Brage & Leardini, 2018). The SEQ region is situated where the subtropical and temperate regions converge, also known as the *Macleay-McPherson overlap*, allowing the fluvial networks within this domain to be rich with biodiversity (Brage & Leardini, 2018). Having a sub-tropical climate that experiences both wet and dry seasons, SEQ's annual seasonal pattern is comprised of a humid and rainy spell before an extended warm and dry period, with an annual precipitation of 1177 mm (Tangney, 2015; Brage & Leardini, 2018; Kemp, 2015). Tropical weather patterns arising from this climate impact strongly upon the streamflow of the region's river systems (Kemp *et al.*, 2015). SEQ is affected by climatic changes related to the El Niño-Southern Oscillation phenomenon and extended periods of the Interdecadal Pacific Oscillation (Tangney, 2015; Brage & Leardini, 2018). The region experiences long droughts before heavy wet seasons, during which large floods are likely to reoccur (Brage & Leardini, 2018, Cook, 2019). Droughts are brought about in eastern Australia by the El Niño period while La Niña drives the onslaught of heavy rain (Cook, 2019). SEQ also experiences the Madden-Julian Oscillation which heightens the likelihood of rain weekly to monthly (Cook, 2019). The combination of such climatic factors and its position at Australia's land mass periphery create a greatly unpredictable climate surrounding Brisbane and SEQ, often experiencing recurrent and extreme hazard events such as floods, storms, droughts, cyclones and bushfires (Tangney, 2015; Brage & Leardini, 2018). Climate change is expected to exacerbate droughts and intensify rainfall, therefore generating worse floods over time and present a constant challenge for local and state governments in SEQ, (Fryirs *et al.*, 2015; Tangney, 2015).

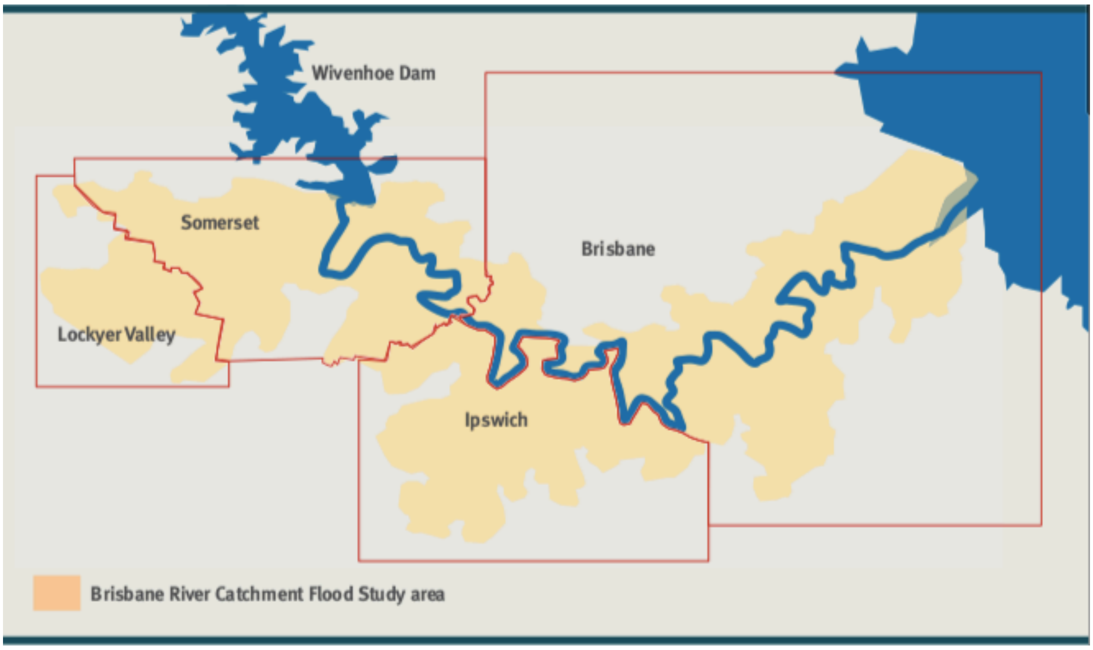
The Brisbane River network's current route was generated around 10 million years ago, however the network itself has existed for an estimated 40 million years (Cook, 2019). Van den Honert & McAneney (2011) describe the Brisbane river as SEQ's longest river, stretching from the Brisbane Range, located north-west of Brisbane, to the Stanley River where the Somerset Dam sits. The river then joins up with Lake Wivenhoe, which is the primary source of water for Brisbane and where the Wivenhoe Dam is located (Van den Honert & McAneney, 2011). From the Wivenhoe Dam, the river flows east to join up with the Ipswich's Bremer River, travelling through Brisbane before reaching Moreton Bay (Van den Honert & McAneney, 2011; Kemp *et al.*, 2015), shown in Figure 4.1. Largely rural land, the 13,570 km^2 Brisbane River catchment also comprises of the urban areas of Brisbane, Ipswich and other settlements (Van den Honert & McAneney, 2011; Cook, 2019), shown in Figure 4.2. Out of the Brisbane City Council's 185 suburbs, the river runs through 43 suburbs, where the urban development has occurred around the river's meanders (Cook, 2019). Weaving through Brisbane are 35 creek catchments that connect to the river and Moreton Bay (Perera & Iezzi, 2017).

Figure 4.1 *Brisbane River Catchment and Floodplain.*



Note. Overview of the Brisbane River catchment and floodplain (image source: Queensland Reconstruction Authority, 2017a).

Figure 4.2 *Brisbane and Neighbouring Localities.*



Note. Closer view of Brisbane and its neighbouring localities along the Brisbane River.

Brisbane, as SEQ's largest city by population, is well-known for being built on a floodplain (Box *et al.*, 2016), As part of a river, a floodplain is produced from the combination of silt, sand and mud that settles from flood events (Lübken, 2012, Cook, 2019). A floodplain exists as a transitional ecosystem that changes according to the seasons and water level (Lübken, 2012). Although the catchment of the Brisbane River is described to have a "low average rainfall/run-off ratio" (Cook, 2019, p. xi), its streamflow fluctuates tremendously due to irregular tropical cyclones and weather patterns (Cook, 2019; Rustomji *et al.*, 2009; Kemp *et al.* 2015). River systems naturally flood (Cook, 2019; Brage & Leardini, 2018), however "it's only when settlements are inundated that this overflow is labelled a flood" (Cook, 2019, p.viii); this is demonstrated in the case of Brisbane. Contemporary societies do not perceive rivers as active systems, instead prescribing dimensions and requiring their distinction from floodplains; this style of thinking dates back to the early Euro-American settlers in North America and the hydraulic mission of colonial bureaucracies (Lübken, 2012; Molle *et al.*, 2009).

The undulating topography of Brisbane therefore creates challenges in identifying flood-prone locations, especially low-lying locations that are further from the river; Ipswich experiences a similar issue with the Bremer River (Cook, 2019). It is recorded that only minor geomorphological changes have been identified after SEQ's major floods, which have a return interval of approximately 10 years as compared to annual or biannual floods (Fryirs *et al.*, 2015; Brage & Leardini, 2018). As a result of past large floods, the Brisbane River's substantial macrochannels contribute to the network's comparative resilience towards extreme flooding (Fryirs *et al.*, 2015; Brage & Leardini, 2018).

4.2 Brisbane's History of Floods

The Brisbane River network's natural hydrological patterns included flooding events which were recognised by the indigenous Turrbal and Jagera people before the 1824 colonisation by the British (Cook, 2019). Although no extensive settlements were constructed by the Turrbal and Jagera people apart from tribal villages, to an extent they did modify the Brisbane River basin on which they inhabited (Brage & Leardini, 2018). This was through firestick farming, which involved the use of fires to burn parts of the forest so as to assist hunting (Brage & Leardini, 2018). However, the Aboriginal people recognised the importance of wetlands and rivers; through extensive and comprehensive engagement with their environment allowed them to intimately understand the necessity in "maintaining the integrity of the environment and to avoid natural hazards" (Brage & Leardini, 2018, p. 95).

After European settlement on the floodplain, as noted by Cook (2019), the settlers perceived the floods to be destructive and therefore challenged the western concept of growth and control. The current understanding of Brisbane's climate variability and social perceptions can be supported by three main forms of knowledge: established documentation from the 1824 European settlement of floods and droughts, verbal accounts of environmental knowledge from the Aboriginals and the shared flood memory of Brisbane's inhabitants (Brage & Leardini, 2018). Although floods are persistent and variable, research has not adequately grappled with singular incidents and their impacts (Lübken, 2012). Moreover, there is a lack of knowledge around subtropical fluvial patterns as compared to temperate fluvial processes, hence monitoring the Brisbane river would require consideration of "a higher degree of uncertainty" (Brage & Leardini, 2018, p. 93).

The earliest records show flooding within the Brisbane River Basin occurred in 1824 (Bureau of Meteorology, 2017). The floods of 1841 and 1893 were inferred from the Brisbane River record to have levels surpassing that of 2011's flood peak; at 8.43 m and 8.35 m respectively, they were the largest recorded gauge heights (Fryirs *et al.*, 2015, Van den Honert & McAneney, 2011; Bureau of Meteorology, 2017). Flood gauge data demonstrate that large floods also took place in the SEQ region in the 1980s and 1990s (Fryirs *et al.*, 2015). SEQ's extensive record and memory of big floods were mainly due to the high flow variability present (Fryirs *et al.* 2015; Rustomji *et al.*, 2009). The floodplain, on which Brisbane was located, was largely inhabited after 1893 as no large floods occurred in Brisbane from then until 1974 (Brage, & Leardini, 2018). During this period, the inhabitants paid no heed to the risk of flooding (Brage, & Leardini, 2018), but wanted to augment the river flow around corners and obtain gravel and sand through dredging, which unexpectedly helped to alleviate flooding (Denham & Hogan, 2014, as cited in Brage & Leardini, 2018).

Before the 2011 floods, the most prominent flood experienced by Brisbane and its neighbouring areas was the flood of 1974, where the river rose to 5.45 m and peaked at 6.6 m, resulting in the worst flood-related damage in Australia's memory (Fryirs *et al.*, 2015; Bureau of Meteorology, 1974, Van den Honert & McAneney, 2011). In Ipswich, damage was suffered by over 2,000 properties, with numerous homes obliterated, and millions of dollars' worth of damage to infrastructure, properties and businesses (Bureau of Meteorology, 2017). Likewise, Brisbane's low-lying areas were inundated, with over 8,000 properties damaged or ruined and $200 million worth of damage to businesses and infrastructure (Bureau of Meteorology, 2017). The lives of two people and 14 people were lost in the floods that occurred in Ipswich and Brisbane respectively (Bureau of Meteorology, 2017).

Brisbane's flood mitigation strategies were re-evaluated after the 1974 flood; it was discovered that although flood maps had existed since 1944, they were relatively unheard of by policymakers (Brage & Leardini, 2018). Furthermore, a flood warning system was set up in 1966 to assist with the forecasting of flood heights and timing of flooding of the Brisbane River, measured at several points downstream (Brage & Leardini, 2018). However, the consequences from the 1974 flood could have been alleviated if the application of the flood maps and flood warning system were more effective and better understanding from the community about the flood forecast (Bureau of Meteorology, 1974). With the aim of managing and capitalising on the river and alleviating flooding, engineers modified and cleared out the riverbed and built the Somerset Dam in 1959 (Cook, 2019). The Wivenhoe Dam and its associated lake was constructed in 1984, after the 1974 floods transpired to help prevent future floods in Brisbane. However there were criticisms against this approach due to the prevailing hydrological patterns which signalled the inevitability of floods (Kemp *et al.*, 2015; Van den Honert & McAneney, 2011; Cook, 2019).

4.3 Brisbane Floods of 2011

There were various factors which resulted in the 2011 floods, one of them being the Millennium Drought. The most intense drought that SEQ had faced up till that point was the Millennium Drought, which spanned the years of 2001 – 2009 (Tangney, 2015). Caused by El Niño weather episodes, the Millennium Drought was a combination of events: a drought occurring from 2002 – 2003, extremely low rainfall during the rainy seasons in the following years and another drought event from 2006 to 2007 (Tangney, 2015). So severe was the prolonged Millennium Drought that in 2007, it resulted in the drastic drop in the total water supply of SEQ to 20% and the Wivenhoe Dam had only 15% of its full supply capacity remaining (Tangney, 2015). Subsequently, heavy monsoonal rainfall fell during September to November 2010, saturating the Brisbane catchment rainfall, followed by an unexpectedly intense La Niña event which brought about intense rain from December 2010 to early January 2011 (Tangney, 2015; Van den Honert & McAneney, 2011; Bureau of Meteorology, 2017). This period of heavy rain was another contributing factor to the 2011 floods as the rain was unable to be contained within the saturated catchment, leading to the first severe flooding event within the Brisbane River catchment, Lockyer Valley and neighbouring areas of SEQ, in particular creek and flash flooding (Tangney, 2015; Van den Honert & McAneney, 2011).

Through the interim report by the Queensland Floods Commission of Inquiry (QFCI) (2011), the Australian Bureau of Meteorology had predicted the severe weather and informed the Queensland Cabinet in October 2010 of the high likelihood of extreme rainfall occurring over November 2010 to January 2011, an intense La Niña event lasting till around March 2011 and a period of cyclones. However, no measures were taken by the operators of the dam to lower the full supply level so as to increase the capacity to contain the forecasted heavy rainfall (Van den Honert & McAneney, 2011; QFCI, 2011). This was due to their assumption that lowering the level would have little benefit over concerns around water security for SEQ's expanding population (QFCI, 2011; Tangney, 2015) and did not account for uncertainty in their forecasting (Brage & Leardini, 2018). The water supply dimensions of the Somerset and Wivenhoe dams in 2011 were 370,000 mL and 1,150,000 mL respectively, while their short-term flood storage was 520,000 mL and 1,450,000 mL respectively (Joint Flood Taskforce, 2011; Kemp *et al.*, 2015), further demonstrating that the dams were then prioritised for water supply over flood management. 370 mm and 480 mm of intense rainfall during January 2011 into Somerset and Wivenhoe Dams respectively resulted in significantly elevated levels of water in both dams (Van den Honert & McAneney, 2011). Heavy rainfall was also experienced in the areas downstream of the catchment: an estimated 450 mm of rainfall was received in Lockyer Creek catchment, 420 mm in the Bremer River catchment and 110 mm – 160 mm in Brisbane's south and eastern suburbs (Insurance Council of Australia, 2011).

The lack of measures from the authorities before the predicted severe weather period combined with the dam operator's decisions during the intense precipitation of January 2011, was the third factor in the 2011 floods. With the severe rainfall, Somerset Dam's water releases and upper catchment runoff, it became imperative for the Wivenhoe Dam to assist in containing the burgeoning amount of water (Van den Honert & McAneney, 2011). The inflows received by both dams were recorded to be twice the amount of that received in 1974 (Bureau of Meteorology, 2017). It should be noted however, that high inflow volumes and rates will decrease the dams' capacity in alleviating floods and the diminish the decision-making alternatives available to the dam operators (Van den Honert & McAneney, 2011). Any outflows from the dams were postponed by South East Queensland Water (Seqwater) as per the guidance from its operational manual, until all options were exhausted (Van den Honert & McAneney, 2011; Seqwater, 2011).

Explained by Seqwater (2011), Wivenhoe Dam experienced two flood peaks: the first flood was able to be contained by Somerset and Wivenhoe Dams but resulted in the dams' flood storage chambers being considerably full. There was little time to release the water from the previous flood which prevented the dams from accommodating the second flood (when it occurred), leading to a dam release floodwave into the Brisbane River (Seqwater, 2011). This was the second major flood event that occurred. The floodwave also contributed to backwater flooding of Lockyer Creek, its tributaries and the lower catchment area, and severe damage within Ipswich and Brisbane (Seqwater, 2011; Insurance Council of Australia, 2011). Without the dams however, the damage experienced would have been much greater (Seqwater, 2011). Within the city, the Brisbane River experienced two flood peaks at 4.3 m and 4.46 m (Van den Honert & McAneney, 2011; Bureau of Meteorology, 2017).

Although the flood peaks were not as high as that of 1974, the damage suffered was extensive. Over 15,000 properties were flooded (EMA Disasters Database, 2011, as cited in Van den Honert & McAneney, 2011), with the evacuation of over 3,600 houses (Van den Honert & McAneney, 2011). The extreme weather and major flooding were recorded to not only have occurred in Queensland, but also in the states of New South Wales and Victoria (Box *et al.*, 2013). The destruction was widespread across Queensland, with 35 people killed by the floods, more than 200,000 people impacted, 3,570 businesses affected, and estimates of $1 billion – $2.645 billion worth of damages and $4 billion worth of economic losses (Van den Honert & McAneney, 2011; Australian Institute for Disaster Resilience, 2020; Bureau of Meteorology, 2017).

4.4 Types of Flooding in Brisbane

Brisbane experiences heavy flooding driven by La Niña events and tropical cyclones in the decaying stage (Brage & Leardini, 2018). The ensuing heavy rain saturates Brisbane's catchments and causes intensified run-off that results in flash or river flooding (Brage & Leardini, 2018; Van den Honert & McAneney, 2011). We can classify the types of flooding in the following categories:

- Flash flooding
- River flooding
- Overland flow flooding
- Storm tide flooding
- Backwater flooding

Flash floods occurs within Brisbane's creeks as a result from brief and intense rainfall (Brage & Leardini, 2018; Brisbane City Council, 2019). These floods happen especially when Brisbane experiences cyclones and storms, culminating in high water flows and speeds that inundate unforeseen areas with extreme force and without any prior warning (UN-Habitat, 2015; Gruntfest & Handmer, 2001). Gruntfest & Handmer (2001) note that the main driver of the increasing pervasiveness of flash floods, is human activities. Gruntfest & Handmer (2001) maintain that burgeoning populations, growing affluence and dynamic ways of living around the world result urbanisation, development of infrastructure and recreational activities that in the encroach into hazard-prone areas. Higher rainfall levels occurring over recurring short periods exacerbate the frequency of flash floods and severe flooding (Gruntfest & Handmer, 2001; Ghofrani *et al.*, 2016), creating challenges for urban flood management (Bruzzone, 2013) and the early dissemination for warnings and emergency responses (UN-Habitat, 2015). Due to the brief periods and the local level at which flash floods occur, conventional emergency responses are often inadequate: communication routes and dissemination of alerts are impeded and rescue operations are delayed (Gruntfest & Handmer, 2001). Flash floods also prevent learning and adaptive responses as well as emergency contingency plans to be developed effectively (Gruntfest & Handmer, 2001).

The type of flooding that attracts most attention both within Brisbane and internationally due to the severity of its impacts, is river flooding. River flooding in Brisbane is less common but occurs at a higher intensity when extended rainfall takes place over the river catchment and the river is unable to contain the excess rainfall (Brage & Leardini, 2018; Brisbane City Council, 2019). Riverine floods can be classified under the categories of slow-onset, rapid-onset and flash floods (UN-Habitat, 2015). Occurring at slow rates, slow-onset floods can persist across several weeks or months, while rapid-onset floods develop swiftly and prevail over several days (UN-Habitat, 2015). Increasing water levels are better predicted for slow-onset floods, allowing the evacuation of people from affected areas, whereas rapid-onset floods hinder fast preventive and emergency responses, resulting in larger impacts to affected people and areas (UN-Habitat, 2015).

Localised flooding within Brisbane is caused by overland flow, which results from excess rainfall that flows off surfaces after a period of rain, underground water that ascends to the surface, or water that has overflowed due to an exceedance of the stormwater drainage systems (Brisbane City Council, 2019). Obstruction of the natural downstream flow paths of overland flows will cause pooling, acting similar to a dam and eventually developing into overland flow flooding that typically impacts localised sites (Brisbane City Council, 2019; Auckland City Council, n.d.). Increased rainfall, impervious surfaces in urban areas, expansion of urban centres, flood plain development and shortage of adequate grey infrastructure are drivers of overland flow floods (Ashley *et al.*, 2005; UN-Habitat, 2015).

Brisbane also receives storm tide flooding from storm surges or king tides (Brage & Leardini, 2018; Brisbane City Council, 2019). Storm tide flooding can affect urban areas when "a storm surge creates higher than normal sea levels" and results "when a low atmospheric pressure meteorological system and strong on-shore winds force sea levels to rise above normal levels" (Brisbane City Council, 2019, para 12). Low-lying urban areas, areas in proximity to the foreshore and waterways that are affected by tides, are particularly prone to storm tide flooding resulting from storm surges (Brisbane City Council, 2019). Due to the convergence of creeks to the Brisbane river, the creeks can experience backwater flooding when storm surges and tidal forces occur (Brage & Leardini, 2018).

4.5 History of Brisbane's Urban Planning

After the British settlement in the Brisbane River catchment in 1824, the low-lying areas became home to the less wealthy while the affluent situated themselves on the hills (Hamnett, 1984). That all changed after the 1893 floods, when the low-lying areas were affected and then deemed unsuitable for habitation (Spearitt, 2009). Brisbane was initially developed according to the European-style town grids, however the settlers' motivations for progress and growth led to the disassembling of the bureaucratic restrictions and the haphazard expansion beyond the town plans (Brage & Leardini, 2018). Initially described as spatially linear due to the city developing around its rail network and planning decisions, Brisbane's spatial pattern eventually extended out with the railway network connecting to other townships and cities (McCarty, 1970, as cited by Spearritt, 2009; Hamnett, 1984). It is suggested that due to prolonged uncontrolled urban sprawl, Brisbane's city plans from 1976 predominantly had a focus on redeveloping the inner-city areas, urban consolidation and densification of inner-city suburbs (Tangney, 2015). Urban planning was eventually taken more seriously from the 1990s, however the *laissez-faire* attitude towards urban planning and policy continued within the Australian federal government and especially within Queensland (Spearritt, 2009; Gillen, 2006). Brisbane's environmental history is broadly recognised alongside urbanisation by its citizens, but they may lack long-standing ecological knowledge similar to that which was accumulated by the Turrbal and Jagera people (Spearritt, 2009; Brage & Leardini, 2018). Due to pressures from land use, the environment and infrastructure, there is a growing interest around how urban form affects sustainability within Australian city and regional planning (Gillen, 2006).

The city of Brisbane swiftly expanded in the past 30 years beyond its history as a river port to become one of Australia's largest urban cities (Spearritt, 2009; Australian Bureau of Statistics, 2020). As of the 2016 Census, an estimated 2.2 million people live in Brisbane, the capital of Queensland (Australian Bureau of Statistics, 2020). Brisbane neighbours the Gold Coast and the Sunshine Coast, where the three areas combined make up 'the 200 km city', as termed by Spearritt (2009). Brage & Leardini (2018) contends that although the Brisbane City Council (BCC) is the largest local government, the planning framework is still lacking. This is seen through the uncontrolled and swift urban expansion, indicating the lack of action towards regulating urbanisation (Spearritt, 2009). It has also created difficulties in identifying the boundaries between Brisbane and the Gold Coast, and generated policy obstacles around land use and infrastructure (Spearritt, 2009). With the city expanding and the growing attraction towards high-rises from the late 1960s, the need for transport infrastructure has led to the separation of the urban areas from Brisbane's green spaces but also the river, Brisbane's most precious resource (Spearitt, 2009; de Manincor & Jones, 2014; Brage & Leardini, 2018). Brisbane's exponential growth in the SEQ region paired with regional planning tensions, along with public calls for more robust regional planning efforts led to the development of a regional planning framework (Gleeson *et al.*, 2010). The importance of urban planning was then established through the state government's delivery of the *South East Queensland Regional Plan* in 2005, and subsequent reviews of the plan in 2009 and 2017 (Brage & Leardini, 2018; The State of Queensland, 2009; Queensland Government, 2017). The SEQ Regional Plan 2017 will be addressed in detail in Chapter 6.

4.6 Brisbane's Urban Governance and Planning Processes

The Australian government comprises three levels of government namely, the federal government (also known as the Australian Government), state and territory government, and local government (Parliament of Australia, n.d.). Instead of the federal government, planning for land use and natural hazards are primarily performed through state and territory authorities, then practiced through the local governments (Burton, 2017). In Brisbane's case, planning is conducted through the Queensland Government followed by BCC, where the Australian Government's hierarchical nature denotes that state authorities control the delegation of powers and responsibilities for their administrative local governments (Burton, 2017). Hence the Queensland Government regulates the BCC's policies and plans, which then informs its local neighbourhood plans. As the unitary local government for the Brisbane metropolitan area, the BCC oversees 26 wards and regulates sectors such as planning, construction, transport, infrastructure, the natural environment and stormwater through the *City of Brisbane Act 2010*, while its water supply and sewage is managed by Urban Utilities, a separate authority under the Queensland Government (Gleeson *et al.,* 2010; BCC, 2020a.; Urban Utilities, 2018; Bajracharya & Khan, 2020).

Formed through an amalgamation of local councils and municipalities, which is often done by Australian state and territory governments when reform is to be undertaken (Sinnewe *et al*., 2015; Laverty, 1972), the BCC's scale of responsibilities has led to a public perception of steady governance in Brisbane (Gleeson *et al*., 2010). Advocates of such amalgamations assume that larger local authorities can offer better capabilities such as enhanced services and technology; have increased influence with upper government and are more fiscally resourced (Sinnewe *et al*., 2015; Dollery & Robotti, 2008, as cited in Sinnewe *et al*., 2015; Burton, 2017). However, information was lacking on how BCC's size affects its performance until research done by Sinnewe *et al*. (2015) compared BCC against a sample of SEQ and New South Wales councils. Sinnewe *et al*. (2015) demonstrated that from 2008-2011, BCC had low financial flexibility, financial resources and liquidity, where its low liquidity affects its financial ability to cover its debts and future provision of various services. The authors also distinguished that the BCC was only able address its debts using its revenue in 2008 and 2011; but was performing well in infrastructure investment, where it had the capacity to supply and maintain sufficient public infrastructure. Observations through Sinnewe *et al*. (2015) showed that BCC's size did not positively correlate with its past financial performance, and indicated that it was not necessarily better-resourced; this will provide some context around BCC's capacity towards investing and prioritising flood risk management and accordingly BGI, for the findings in Chapter 8 and the overall aim of this research.

Despite the general public perception, Gleeson *et al*. (2010) argues that Brisbane, like other major Australian cities have "complex, overlapping and often haphazard governance arrangements" (p. 1) leading them to experience deficits in governance, categorised into planning and democratic deficits. To an extent, the deficit in the metropolitan planning sector indicates an insufficiency in governmental access and support to planning and its associated sectors; the lack of integration by state organisations; and its processes being complicated by the interests of the private sector which are to facilitate development, lower costs and adherence to regulations (Gleeson *et al*., 2010; Bajracharya & Khan, 2020). This is noted where recurrent changes to the Queensland Government's planning legislation due to political and development pressures, constrain the capacities of the planning sector (Bajracharya & Khan, 2020). The BCC is seen to have a level of involvement with the Queensland government in terms of decision-making and appears to prioritise the construction of transport infrastructure within land use planning, due to political and community pressure around infrastructure services and wellbeing (Gleeson *et al*., 2010).

The democratic deficit, on the other hand is derived from a lack of autonomy and equity, where the planning sector lacks an impartial and independent arena to operate shared "planning will" (p. 1), along with uncertainty around the exact political responsibilities held by local and state governments (Gleeson *et al.*, 2010). This necessitates more effective organisation and collaboration between the Queensland Government and the BCC (Bajracharya & Khan, 2020). The BCC has been observed by Bajracharya & Khan (2020) to place significance on involving the public within their decision-making, guided by the *City of Brisbane Act 2010*, and reflected within the BCC's *Community Engagement Policy* through the provision of information, public consultation and active participation. Public engagement is largely regarded as essential to navigate governance issues and for planning to be effective (Bajracharya & Khan, 2020; Knapp, 2017). Moreover, collaborative planning is recommended for better consideration of public views, assists in finding alternative solutions, representation of community groups and rallies the public involvement for community initiatives, however it is can be hard to implement in industry practice (Knapp, 2017) especially with Brisbane's extensive population. Examples of public engagement and collaborative planning projects that the BCC has undertaken will be discussed in Chapter 6 and 8.

4.7 Conclusion

This chapter provides a contextual overview of the Brisbane. Brisbane is seen to have a subtropical climate that experiences wet and dry periods and other climatic phenomena which makes it prone to extended droughts and intense rainfall that can culminate in large floods. The city's vulnerability to floods is also a consequence from being located within the Brisbane River catchment and on the Brisbane River floodplain; it has had a long history of floods, especially large river floods that have caused extensive damage. The most recent large flood was that of 2011, which was triggered by extended drought and then severe rainfall, and exacerbated by the inaction around lowering dam levels, resulting in severe flooding in Brisbane and its surrounding areas. Apart from river flooding, Brisbane also experiences flash floods, overland flow floods, storm tide floods and backwater floods, which presents challenges for the city's flood risk management framework.

Brisbane's relationship with urban planning is also detailed in this chapter, where urban planning became better received in only as recent as 1990s and coincided with the city's exponential growth and infill development, which has continued up till now. Hence, robust planning and urban governance efforts are important for Brisbane’s future; some of the strategies around development that relates to flood risk management will be covered in Chapter 6. BCC's responsibilities are defined by the state, however from the literature, their planning and decision-making processes are seen to be somewhat ambiguous and constrained by the complexity of institutional arrangements across all tiers of government, tensions around planning and governance and the influence of the private sector towards development. The literature also indicated that despite the BCC's size, it did not correlate to high financial and resource capacities but found that the BCC placed importance upon the provision of infrastructure and public involvement. Flood risk management in Brisbane is influenced BCC’s focus on infrastructure and public involvement, and impacted by the issues around planning, decision-making and financial capacity, hence these areas will be further expanded upon in Chapter 6 and 8.

5 Singapore Context

Singapore was chosen as a case study for this research as it is widely regarded as a best-practice model for integrated stormwater management and the nation-wide use of Blue-Green Infrastructure (BGI) –type strategies to boost the existing drainage network as well as provide multiple benefits to the environment, urban liveability and sustainability.

The chapter begins with an examination of the climate and geographical context of Singapore. Noting the intensity of high rainfall and runoff that have occurred as a result of the extent of impermeable surfaces, the country's urban planning and governance looks to counteract this. It then examines the history of floods in Singapore, noting that large floods in the past have caused significant social, infrastructural and environmental damage. In particular, the chapter has a specific focus on the way the Singapore Government has evolved its planning and public policy in terms of drainage, waterbodies, recreational uses and sustainability; and its institutional structure to later form the Public Utilities Board (PUB), which contributed to the reduction in the intensity and frequency of large floods over the years. The latter part of the chapter details the embracing of BGI in planning through the efforts of the PUB and other government agencies and demonstrates its significance for current flood risk planning efforts.

5.1 Singapore's Climate and Geography

Singapore, an equatorial island city-state, has a tropical climate and endures large amounts of rainfall, elevated and consistent temperatures and humidity all year round (Meteorological Service Singapore, n.d; PUB, 2018a). Singapore experiences two main monsoon seasons, the Northeast Monsoon (December – early March) and the Southwest Monsoon (June – September) with inter-monsoonal periods in between. As an island, Singapore also has a coastal climate with temperatures in coastal areas tempered by the surrounding sea (Meteorological Service Singapore, n.d.). Singapore has a land mass of 721.5 km^2, consisting of the mainland and additional smaller islets, where the topography is undulating, and mostly situated an average of 15 m above sea level, although 30% of the country sits below 5 m above sea level (PUB, 2018a).

Meteorological Service Singapore (MSS) (n.d.) and the Expert Panel on Drainage Design and Flood Protection Measures (EPDDFPM) (2012) report that during the first half of the Northeast Monsoon season, monsoon surges generate extensive, sustained moderate-to-high intensity rain accompanied by strong winds and sudden bursts of showers in the afternoon and early evening, while the later part of the Northeast Monsoon is comparatively dry with winds. This is followed by an inter-monsoon period comprised of sudden average to heavy thunderstorms during afternoons and early evenings, and temperatures in the afternoon are often high. The Southwest Monsoon that occurs after brings the ‘Sumatra squalls’ which are an ordered formation of thunderstorms that drift east to Singapore from Sumatra or the Straits of Malacca, generating winds of 40 – 80km/h and brief showers or thunderstorms during the afternoon. The next inter-monsoon period also contains average to heavy thunderstorms, however higher rainfall overall occurs compared to the previous inter-monsoon period (MSS, n.d.; EPDDFPM, 2012). Singapore receives around 100 mm to over 300 mm of rainfall monthly and around 2,340 mm of rainfall yearly, where rainfall often occurs at high intensity, on average 167 days annually (where the total rainfall is 0.2 mm or greater). and fluctuates from month to month (PUB, 2018a; MSS, n.d.). Tropical cyclones arising in neighbouring locations may also indirectly impact Singapore’s rainfall when rain and winds patterns travel and coincide over Singapore (EPDDFPM, 2012). As such, intense tropical rainstorms are often experienced in Singapore.

Observations from the MSS (n.d.) note that Singapore's climatological variables fluctuate hourly every day rather than monthly, largely due to solar heating and rainfall during the day. Singapore's northern and western areas receive higher amounts of rain compared to its eastern areas. They record that temperatures typically peak at 31–33°C in the day and fall to 23–25°C at night, with higher temperatures occurring around the cusp of the inter-monsoonal period and the Southwest Monsoon and lower temperatures occurring at the start of the Northeast Monsoon. Humidity also fluctuates daily rather than monthly, ranging from above 90% in the early hours of the morning to 60% on dry afternoons and 100% during extended rain spells (MSS, n.d.). The rainfall outlook in Singapore, although fluctuating yearly, has been recorded to have grown in intensity and frequency annually from 1980 – 2018, where it has heightened to an average of 97 mm every 10 years, and is theorised to be due to urban growth and global warming (MSS, n.d.-a; PUB, 2014). The drainage network also experiences pressure from the different types of rainfall incidents, where some measures may manage rainfall from brief heavy storms better than extended storms (EPDDFPM, 2012). This demonstrates the importance of having a range of measures to manage stormwater effectively as part of flood risk management so as to prepare changing climate trends in the future.

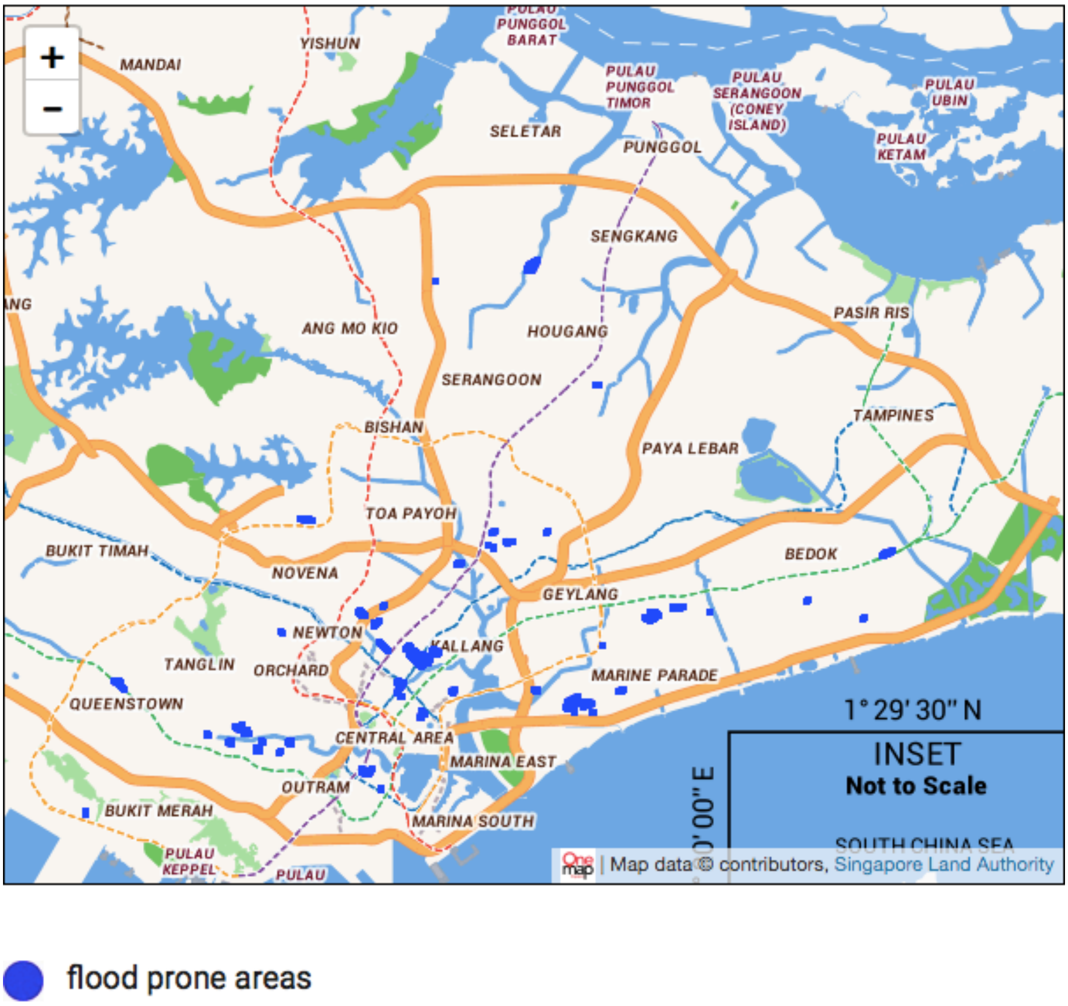
5.2 History of Floods

The high frequency and intensity of rainfall and rainstorms that Singapore experiences as a result of its tropical climate and monsoon seasons can result in frequent floods. These are commonly flash floods occurring due to specific localised factors. Firstly, when drains or canals are unable to accommodate the rainfall and runoff arising from severe storms, the spillage of excess stormwater onto nearby areas may instigate a flash flood (PUB, 2014). Singapore's topography, featuring localised depressions in the ground and roads which will inevitably collect water, also constrain the ability to modify stormwater infrastructure in low-lying and seaside areas to align with downstream levels (PUB, 2014). These low-lying areas are typically situated near the south and east coastlines, with some in the inner parts of the country (Tan *et al.,* 2009). Obstructions in drainage systems from debris or plant matter during storms can hinder the systems' ability to convey stormwater effectively, resulting in flash floods (PUB, 2014; Tan *et al.*, 2009). Furthermore, new developments may have more impervious surfaces which decrease ground infiltration, leading to higher volumes of surface run-off (Tan *et al.*, 2009). Floods have also been attributed to the occurrence of high tides leading to storm surges, sometimes in addition to intense downpours, where the public drainage network was unable to cope with high volumes of seawater flowing through (Lee & Wong, 2000; The New Paper, 2004; The Straits Times, 1935; 1957).

While many of Singapore's floods were not often severe, major flood incidents have occurred from 1932 to the 2000's in central and low-lying areas where floods can range from the knee to the chest level (Koh, 2019; The Straits Times, 1949; The Straits Times, 1978a; Yeo, 1987). A significant major flood occurred in 1969, where intense rain flooded numerous areas of Singapore and deluge heights reached waist level (The Straits Times, 1969a). Five people were killed by the floods, livestock were lost, thousands of people were isolated, and many needed to be rescued via helicopter after seeking safety on roofs and in trees (The Straits Times, 1969a; Yeo, 1987). The floods also obstructed transport connections and flights, and impeded communication and electricity systems (The Straits Times, 1969a).

Subsequently, when the 1978 floods transpired, it was considered to be one of the worst floods since the 1969 event (Koh, 2019). Between the 2nd and 3rd of December 1978, around 512 mm of monsoonal rain (approximately a quarter of Singapore's annual rainfall) was recorded to have fallen over 24 hours (The Straits Times, 1978b; EPDDFPM, 2012). Seven lives were lost, with over 1,000 people needing rescue, widespread destruction to property and livestock, communication and electricity systems were impacted and landslides occurring in several areas including housing estates (Knutty, 1978; The Straits Times, 1978a; 1978c; 1978d; Yeo 1987). The 1978 flood caused $5.75 million in damage (EPDDFPM, 2012). Significant flash floods occurred in 2010, 2011, 2013 and even till this present day but at a lesser intensity than those experienced before 1978 (Koh, 2019; Channel News Asia, 2020). Figure 5.1 shows an example of the areas in Singapore that are most at risk of floods.

Figure 5.1 *Flood-Prone Areas in Singapore's Central Watershed*



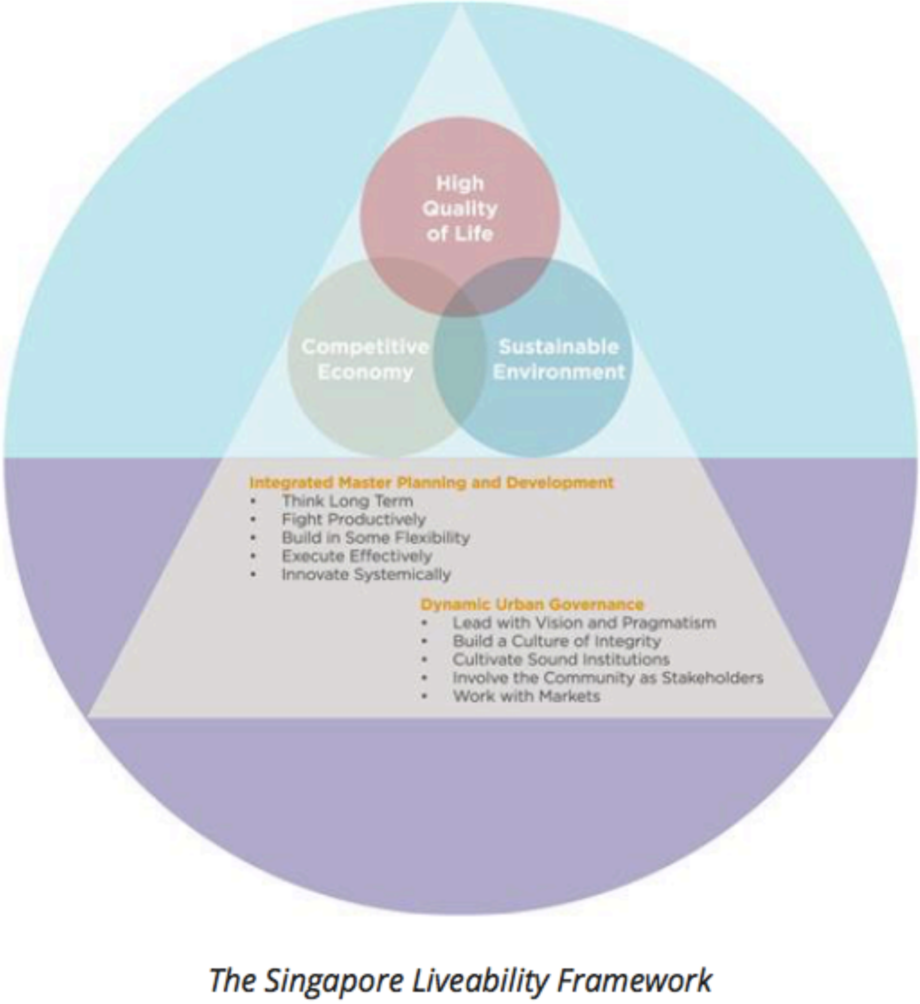
Note. A map overview of the most flood-prone areas located in the central watershed of Singapore (image source: Singapore Land Authority & Public Utilities Board, n.d.).

5.3 Urban Planning and Governance

Singapore's centralised urban planning approach, particularly the way in which it plans for the management of flood risk, can be attributed to its centralised government which has been dominated by the People’s Action Party since the country’s first election in 1959 following its independence. The approach pioneered by Lee Kuan Yew, Singapore’s first prime minister, has been widely discerned as committed to life-long learning, decisive, corruption-intolerant, country-focused and innovative (Ho, 2015; Juma, 2013; Rana & Lee, 2015). Choi (2018) also notes broad criticisms that deem Singapore’s governance approach as autocratic compared to western societies. Allam (2020) notes that locally, Singapore is generally seen to have “a strong leadership style" (p. 29) which has led to the country's growth in urban development, public housing and standard of living from its humble origins, although not without criticism. As such, the nature of urban development in Singapore is connected to governance and is impacted by the "type of leader and leadership style adopted" (Allam, 2020, p. 30). Singapore preferred a more autocratic approach in part due to the poor social-economic conditions following the end of British and Japanese rule and the overriding social imperative to unite the country's multicultural demographics (Allam, 2020; Choi, 2018; Ho, 2015).

Lee Kuan Yew's 'soft authoritarian' leadership and governance strategy facilitated the exploration and implementation of concepts that produced concrete outcomes within a minimal amount of time. For example, the public housing scheme rolled out after the establishment of the Housing Development Board (HDB) in 1960 is now regarded as a best practice model (Allam, 2020; Yuen, 2007). Participatory planning however has not been entirely neglected under this governance approach; public perspectives were sought for Singapore's first *Master Plan* in 1952 and its subsequent reviews, as well as in the creation of the Centre for Liveable Cities (CLC) and the Singapore Liveability Framework and in the planning for efficient land use (Allam, 2020; Wong & Fook, 2016 as cited in Allam, 2020). Although public participation is often portrayed as being side-lined in Singapore's technocratic planning approach, local public engagement has been observed to function well under the direction of the agency in charge (Heng, 2016), with public engagement initiatives having evolved over the years to allow more involvement (Tortajada & Joshi, 2013). Public engagement is also incorporated in the Singapore liveability framework (shown in Figure 5.2), which was developed by the CLC (2019) to contribute to Singapore's sustainable development vision and guide its master planning and urban governance approach.

Figure 5.2 *Centre of Liveable Cities: Singapore Liveability Framework*



Note. The Singapore Liveability Framework developed by Centre of Liveable Cities' (image source: Centre of Liveable Cities, 2019a). The top section of the triangle contains the three main outcomes and the lower section defines the urban systems method used in achieving the outcomes.

The Framework underpins various approaches that are used in Singapore's growth and can be used to guide international governments in evaluating urban living and in developing ways to achieve greater quality of life and sustainability. This is especially pertinent for high-density cities which experience constraints on natural resources (CLC, 2019; Khoo, 2012). This Framework in particular informs the strategic thinking of the PUB's Active, Beautiful, Clean Waters (ABC Waters) Programme. Details of the ABC Waters Programme will be addressed in the results of Chapter 7.

Singapore's long-term planning is conducted through the *Concept Plan* followed by the *Master Plan* (Urban Redevelopment Authority, 2020a). The latest *Concept Plan 2011* by the Urban Redevelopment Authority (URA) (2020a), provides strategies around land use, transport infrastructure, and development for the following 40-50 years that aligns with the population's needs, economic performance and urban liveability. Reviews of the *Concept Plan* every 10 years involve the consideration of land demands with applicable agencies and consultation with stakeholders and the public (Chew, 2019). The *Master Plan 2019* is the main statutory land use plan, directing and regulating development for the upcoming 10 – 15 years and undergoing a review every five years (which, much like that of the *Concept Plan*, involves a stakeholder and public consultation) (URA, 2020b). The *Master Plan 2019* renders the strategies of the *Concept Plan 2011* into land use plans for Singapore's planning areas, containing provisions and development controls that provide specific development guidance (URA, 2020b). Following the 2011-2013 review of the *Concept Plan*, the Ministry of National Development launched the *Land Use Plan 2030* which shares the strategies to support an estimated population of 6.5 to 6.9 million by 2030, provide a highly liveable environment and also reserves land for future uses after 2030 (URA, 2020c).

Allam (2020) attributes Singapore's growth to its *Master Plan* and Liveability Framework, along with its governance and urban development approach. This growth has not gone unnoticed by Singaporeans who have benefited from various government projects, for example through the public housing initiative that to date has correlated with over 91% of Singaporeans owning affordable and good quality apartments (Allam, 2020; Guo, 2018). Additionally, increasing community participation in planning processes has helped the government to identify and address local issues (Guo, 2018). For example, through a 2012 – 2014 study conducted by the HDB in conjunction with the National University of Singapore, residents were able to suggest improvements to community bonding and social interaction and partake in pilot projects to produce neighbourhood amenity designs (Guo, 2018). This has spurred wider thinking around development and planning of spaces to enhance liveability (Allam, 2020).

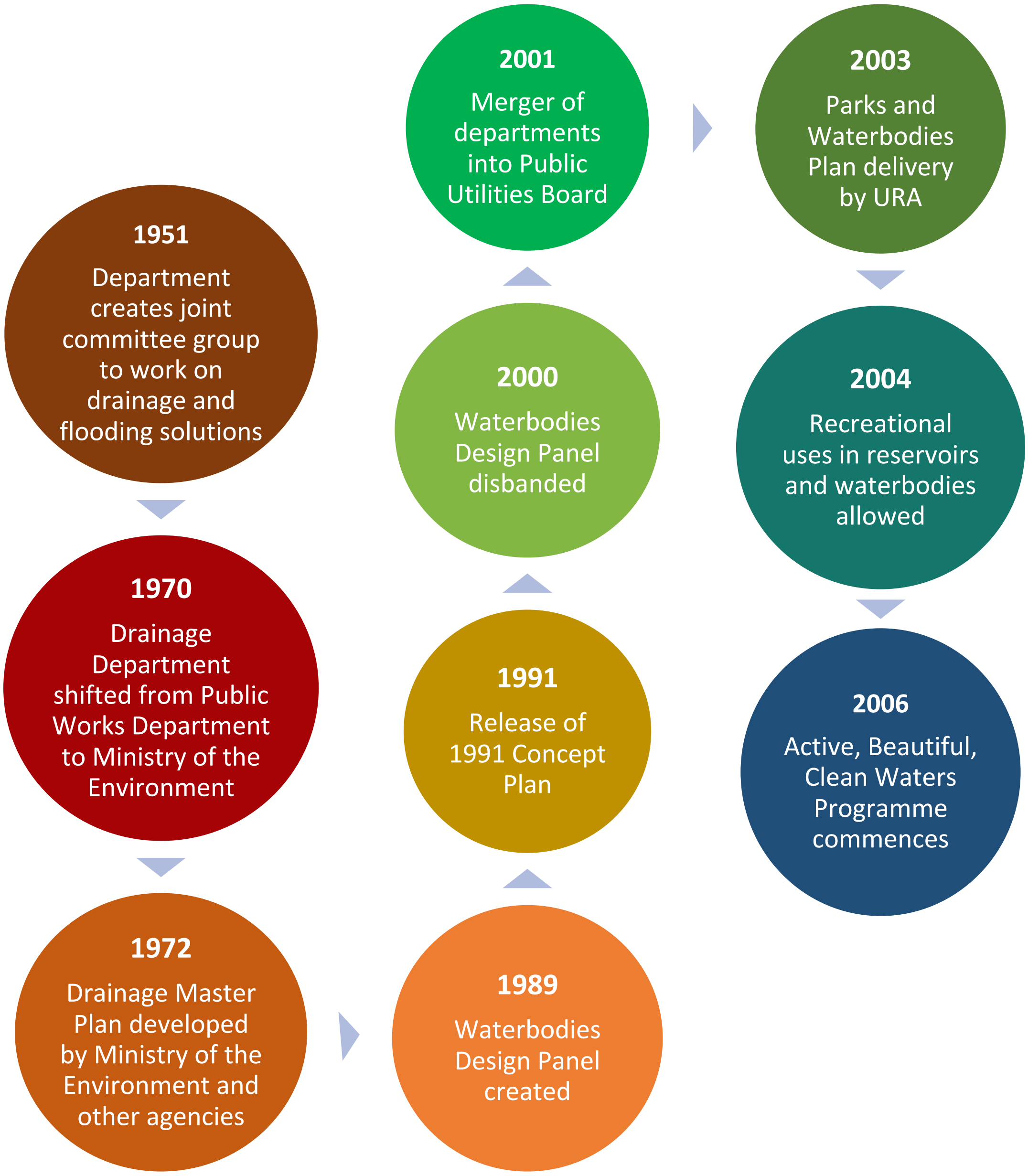
Singapore has also been seen to have a holistic framework towards the planning of water (water resource, flood risk and wastewater) that is rarely seen elsewhere, where developed policies consider the effects on various sectors and the country's development as a whole (Tortajada & Joshi, 2013). Stakeholder and public participation were key to the development and implementation of water-related projects that have allowed Singapore to experience and participate in healthy waterways and the natural environment as part of urban living (Allam, 2020; Tortajada & Joshi, 2013). The next section discusses this approach to water-related projects, with a specific focus on planning for flood risk.

5.4 Journey of Planning for Flood Risks

Singapore's frequent floods have made flood risk management an imperative part of its growing urban landscape and population, reflecting Loh & Pante (2015)'s observation where flood risk management can generally be seen as a political matter, reflecting the most prominent technologies and political agendas present. Loh & Pante (2015) argue that Singapore's way of managing floods followed a high modernist approach which is the "singular belief in the power of scientific megaprojects to master both nature and human nature; it appeals to policy makers of various ideological persuasions" (Loh & Pante, 2015, p. 38). This approach is rooted in Singapore's post-World War II history, where the swift rise in the local and migrant population led to the sprawl of crowded, informal settlements, which was perceived to be one of the contributors to the occurrence of floods. The swift rise of development in the 1950s prompted growing flood risks while the drainage systems struggled to cope (CLC, 2017). At that time, the management of floods and flood risks were primarily the responsibility of government's agencies such as the Drainage Department and the Public Works Department, until the Public Works Department's privatisation in 1999 and the departmental merger of the Public Utilities Board (PUB) in 2001 (Loh & Pante, 2015).

Indeed, Loh & Pante (2015) noted that the manner in which the People's Action Party government sought to regulate floods involved specialist expertise and active modifications along with an "efficient centralised bureaucracy" (p. 43). The authors stated that by focusing on drainage, the government intended to avert floods, promote catchment development and improve land use efficiency across the country. Planning for flood risk management involved master planning at a national level, with local-scale drainage plans to address various land uses and on-site regulations to avoid localised flooding (Loh & Pante, 2015). A chronological overview of the development and changes of institutional approaches in planning to regulate and mitigate flood risks and flooding in Singapore is shown in Figure 5.3.

Figure 5.3 *Chronological Overview of Singapore's Institutional Planning Approaches*



Note. Chronological overview of the development and changes of institutional approaches in planning to manage and mitigate flood risks and flooding in Singapore (content adapted from Centre for Liveable Cities, 2017).

The move to address flood risks and flooding was initiated early in 1951, when the Public Works Department created a joint committee group to work on solutions to ameliorate the public drainage network and mitigate flooding (Koh, 2019). Projects of this nature were administered in a number of residential locations, implementing works such as constructing reservoirs and diversion canals, building drainage and tidal gates, expanding and increasing the depth of drainage and elevating roads (Koh 2019; EPDDFPM, 2012; The Singapore Free Press, 1957; The Straits Times, 1954; 1969b). The politically charged issue of informal settlers versus the government's intention to manage flooding by reinforcing land use control, was later worked upon in the 1960s through a 20-year master plan. This included the provision of public housing flats and establishment of towns through HDB which hoped to better regulate urban development in a centralised governance manner (Loh & Pante, 2015). Goh (2001) observed that the construction of flats was conducted through Five Year Building Programmes that plan for "projected population growth, land sales and housing demand" (p. 1591) in addition to HDB's master plans that provide for particular infrastructure requirements prior to any building works and align with the country's *Concept Plan*.

A reorganisation of responsibilities occurred in the 1970s, to better synchronise efforts towards drainage and flood management: the Drainage Department shifted from the Public Works Department to the Ministry of the Environment (now the Ministry of Sustainability and the Environment) (Tan *et al*., 2009). However, land-use changes and urban growth continued to intensify through the construction of industrial and housing estates, contributing to greater amounts of run-off to the drainage network and exacerbated flooding in the country (Koh, 2019; Tan *et al.*, 2009). In response to increased flooding, the Ministry of the Environment developed the *Drainage Master Plan* in 1972 in conjunction with the URA, HDB, Jurong Town Corporation and several other agencies (Koh, 2019; EPDDFPM, 2012). As a strategic approach to planning and administering drainage systems, the *Drainage Master Plan* aimed to address flood-prone locations, avert floods through the installation of suitable drainage before any new development activities, and protect drainage reserves for future drainage projects (EPDDFPM, 2012; Tan *et al.*, 2009). The guidance provided by the *Drainage Master Plan* aimed to help the relevant government agencies deliberate over the allocation of land use for drainage against housing and road infrastructure, to be assessed by the Drainage Department (CLC, 2017; Tan *et al.*, 2009). Structural infrastructure (often concrete canals) was used to help mitigate on-ground flooding. These were seen to be relatively effective in transporting stormwater during periods of rain but did not mitigate the frequency of flooding (CLC, 2017). Singapore's continued urbanisation posed challenges towards efforts to allay floods, while having the potential to trigger floods in new locations; the Drainage Department were aware of this and felt the pressure to seek more effective solutions (CLC, 2017).

The authorities shifted their attention in the 1980s from post-independence urban issues to improving liveability, with an increased emphasis on the quality of urban living (CLC, 2017). The upgrades were conducted in various public housing estates and newly developed towns such as Serangoon, Toa Payoh and Ang Mo Kio and many others (Loh & Pante, 2015). The later 1980s saw the URA and Ministry of National Development envisaging the concept of re-naturalising local waterways so as to boost the green elements in the urban environment and increase visual appeal, wherein the Waterbodies Design Panel was formed in 1989 with representatives from various public and private agencies for the goal of assessing and guiding the design of key water channels within planning (CLC, 2017; Tan *et al.*, 2009). Support and contributions from the private sector together with public agencies in the Waterbodies Design Panel early on helped to reimagine the potential of Singapore's waterways and enabled selected exhibition sites to be established that otherwise might not have been possible under traditional planning processes (CLC, 2017).

The Waterbodies Design Panel goal was further supported within the *1991 Concept Plan* which acknowledged Singapore's monsoonal climate and scarcity of land. The *1991 Concept Plan* focused on inventive land use planning such as introducing the concept of a 'Green and Blue Plan' which explored the idea of adapting park connectors and waterfront to perform additional recreational uses, and the administering of a *Singapore River Development Guide Plan* to guide effective land usage (Tan, 2019; URA, 1994). As the authority on Singapore's land use planning, the URA recognised the constraints in land availability and conflicting land uses, and aimed to strategically plan its land requisites for infrastructure and create development guide plans that eventually shifted efforts away from Waterbodies Design Panel's exhibition projects (EPDDFPM, 2012; CLC, 2017). The URA later issued Development Control Submission Guidelines to advise water-side developments on controlling the amount of runoff that flowed into the waterways (CLC, 2017). The Waterbodies Design Panel however, disbanded in 2000 due to the absence of an institutional structure to strengthen its long-term role in the hope that the private sector would develop fresh concepts; this did not materialise and any endeavour to revitalise the water channels dwindled (CLC, 2017; Tan *et al.*, 2009). The Drainage Department endorsed, but barely embraced the Waterbodies Design Panel's projects, even when the National Parks Board wholly adopted the Waterbodies Design Panel's Park Connector project, which over time expanded out into a country-wide connector network. This was due to the Department's primary aim of dealing with flood risk, though its procedural structure would have also constrained the Waterbodies Design Panel (CLC, 2017).

In 2001, the amalgamation of the Drainage and Sewerage Departments with the PUB restructured both into an overarching PUB National Water Agency in Singapore to facilitate and consolidate the different goals in regulating water levels (CLC, 2017). The PUB National Water Agency's functions involve regulating local water supply, catchments, stormwater and wastewater, through the main actions of storage, treatment, dispensation and reclamation (PUB, 2020). The *Parks and Waterbodies Plan* was revealed by URA in 2003 as part of the *Master Plan 2003*, focusing on nature reserves, biodiversity-rich nature areas and maximising the functionality of green and blue spaces. The development of the *Parks and Waterbodies Plan* involved previous consultations with environmental organisations and the public (CLC, 2017; Balakrishnan, 2002).

5.4.1 Transitioning towards Blue-Green Infrastructure

A growing shift towards public involvement in blue spaces then saw the permitting of recreational uses within reservoirs (catered to the reservoirs' features) in 2004 by the PUB, where the decision-making involved consultations with stakeholders such as non-governmental organisations and the wider public (CLC, 2017). Hard barriers were replaced with natural ones such as vegetation and rocks to preserve the natural hydrological patterns, redevelop the spaces and visually attract people to connect with water, along with public education on water health and quality (CLC, 2017). These events and the growth of the country beyond its urban issues encouraged the PUB towards adopting a sustainability and public-centric approach, leading to the implementation of the ABC Waters Programme in 2006 (CLC, 2017). The Active, Beautiful, Clean (ABC) Waters Programme's aims to maximise the possibilities and capacities of Singapore's waterways and waterbodies through the holistic integration of stormwater and water supply infrastructure into the wider environment on a national scale (CLC, 2017). Some of the early projects that were finished under the ABC Waters Programme were the transformation of Sungei Api Api from a canal to a deepened river with mangroves and biotopes to filter runoff; the naturalisation of the stormwater collection Pang Sua Pond; and the redesign of the Opera Estate underground pond (CLC, 2017; Tan *et al.*, 2009). Collective inter-agency efforts were seen to be important to the Sungei Api Api project where land use policies were adapted to provide the area with a recreational function when the project surpassed the limits of its drainage reserve area, and the HDB provided assistance with the project's maintenance (CLC, 2017); the finished project is shown in Figure 5.4.

Figure 5.4 *Active, Beautiful, Clean Waters Project Sungei Api Api.*

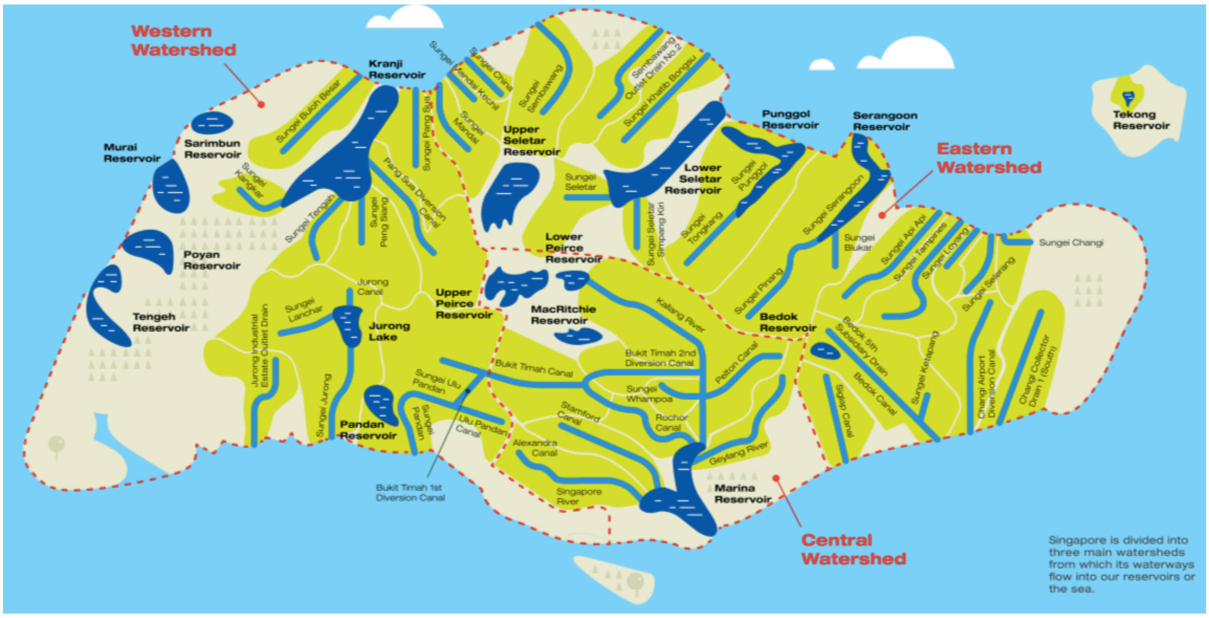
Note. View of a section of the Sungei Api Api transformation (image source: AECOM, 2020).

As the country's main government body that handles flooding and water matters, the PUB has come a long way from predominantly relying on grey infrastructure for flood risk management to an integrated approach that features BGI-type strategies. However, the PUB's technocratic approach to dealing with floods should not be assumed to absolutely prevent floods, due to the nature of climate, topography and development factors that contribute to floods. This was the case for the Orchard Road floods in 2010, where an area had been relatively absent of floods for around 20 years but flooded due to the Stamford Canal having reached capacity from intense rainstorms (Koh, 2019; EPDDFPM, 2012). This led the Expert Panel on Drainage Design and Flood Protection Measures (2012) to include in their recommendations the need to create a strategic public outreach programme to improve education and involvement in PUB's drainage and flood management strategies, in addition to upgrading its flood warning systems, so as to strengthen the public's flood resilience. Loh and Pante (2015) acknowledges that the centralised approach to dealing with floods requires a variety of other knowledge sources and skill sets, especially in an environment that has competing land uses; Singapore could benefit from a deeper level of community involvement by integrating community experiences with the government's expertise to generate flood risk management resources and flood relief efforts.

5.5 Current Flood Risk Planning Efforts

The PUB (2014) has long recognised that the amount of stormwater peak flows travelling from urban areas into canals have increased as a result of this rapid urbanisation. This is largely due to the lack of infiltration from paved surfaces in urban areas as compared to vegetated areas that support ground infiltration. Singapore's geographical size constraints and high population juxtaposed with distributed areas of low-lying land and high rainfall present challenges in stormwater management. Recognising the geographical, meteorological and urban difficulties towards stormwater management in Singapore, the PUB (2014) employs an integrated stormwater management approach with dual goals: to effectively collect and manage stormwater for water supply and flood risk management. For stormwater management, the PUB collaborates with major planning organisations and agencies such as the URA, Building & Construction Authority, Land Transport Authority, HDB and Jurong Town Corporation to harness the expertise and knowledge for effective management of stormwater so as to reduce flood risks (PUB, 2018a). PUB's network of drains, canals and reservoirs cover almost the entire landscape of Singapore, where its waterways span over 8,000km and its reservoirs number up to 17 (shown in Figure 5.5), demonstrating the integral role of waterways and waterbodies and the capacity for them to become part of the urban landscape (PUB, 2014; Centre for Liveable Cities, 2017).

Figure 5.5 *Singapore's 48 Major Waterways and Their Catchments.*



Note. An overview of the Singapore's network of 48 major waterways and their associated catchments (image source: Public Utilities Board, 2014).

Drainage improvement projects are frequently revised and consulted with the appropriate agencies, after which PUB subsequently supplies drainage requisites to the URA's land use *Master Plan* (EPDDFPM, 2012). From the requisite to protect drainage reserves, around 820 hectares have been allocated for drainage reserve in 2012 and consistent drainage upgrades resulted in the decrease from 3,200 hectares of flood prone areas in 1970s to 49 hectares (98% decrease) in 2012 (EPDDFPM, 2012). Over $2 billion has been spent by the country from 1973 on enhancing its drainage networks, which has led to 3,200 hectares of areas with flood risks in 1970s to 30.5 hectares in 2016 (Koh, 2019; Cheam, 2012, as cited in Koh, 2019). This includes the Marina Barrage which dams the Marina Channel to form the Marina Reservoir; the barrage provides the following uses: flood control, water supply and lifestyle attraction (PUB, 2018b). In particular, the flood control functions to mitigate flooding in flood-prone low-lying areas by discharging stormwater into the sea through the operation of nine crest gates during low tide and through seven large pumps during high tide; both components also serve to protect inland waterways from tidal surges (PUB, 2018b; Koh, 2019; Tan *et al.,* 2009). Green features and philosophies are a core part of the Barrage, which are embodied through the building of the Barrage, the design and daily functions so as to be energy and water-efficient (PUB, 2018c). Some features are the Barrage's green roof, double-glazed glass panels, the

Solar Park, natural lighting and ventilation, using reservoir water to cool the generators and drainage pumps and various other energy and water-efficient functions (PUB, 2018c).

5.6 Conclusion

The tropical climate and monsoonal seasons of Singapore lends itself to heavy rainfall that occurs at varying intensity throughout the year and places great pressure on the country's drainage system, indicating the need to have effective stormwater management strategies and measures to help alleviate flood risks. Additionally, low-lying areas, drainage obstructions, the increase in impervious surfaces from growing urbanisation and storm surges contribute to floods in the country. The country has had a history of medium to large floods which has gradually decreased in severity as a result of its centralised governance approach to urban planning and flood risk management, in a bid to guide its development towards more sustainable forms. Establishing an effective flood risk management approach occurred over the years through trial and error, through the setting up and reorganisation of various agency roles, nation-wide master planning, construction of grey infrastructure, and the shift towards developing BGI approaches.

Over the years, the PUB has shown a shift in thinking from predominantly relying on grey infrastructure in flood risk management to now utilising an integrated approach featuring BGI-type strategies within urban planning to achieve multi-functional outcomes. The strategic approach that PUB now undertakes involve drainage upgrades, the ABC Waters Programme and robust partnerships with other government agencies for urban planning. The recognised success of the ABC Waters Programme was highlighted to be attributed to the PUB's proactiveness in trading knowledge, collaboration with other agencies including international best practice, display of pilot projects to garner public support, the willingness to learn from past mistakes and the decision-makers' belief in their vision. These features would be valuable learning points for decision-makers of Brisbane's flood risk management to improve upon the effectiveness of their frameworks.

Overall, Singapore's approach to managing flood risks is the product of a chain of learning events that started with the shift in planning mindsets, the efforts of the Waterbodies Design Panel, the PUB's willingness to engage difficult projects; and the positive stakeholder reception to and involvement in government proposals on maximising the potential of environmental spaces. Further details of Singapore's strategies, approaches and the ABC Waters Programme will be further explained in the results of Chapter 7.

6 Results – Brisbane’s Planning and Policy Documents

This chapter examines the planning and legislative environments of flood risk management and Blue-Green Infrastructure (BGI) practices in Brisbane. This will be contextualised through an analysis of planning and policy documents selected based on their immediate influence and relevance for flood risk management and the role of BGI in regulating flood risks. The focus is on state and local level planning processes for flooding that occurs in urban areas (river, creek and overland flow flooding). As such, this chapter will not include an analysis on storm tide flooding as it is categorised under coastal hazards in planning and policy documents. It is also recognised that BGI strategies are more likely to be included within mid to lower level documents, where BGI applications can be scaled to suit the intentions and conditions of the target locations, thus BGI will only be addressed where present.

The analysis undertaken within this chapter addresses Research Question 1 ‘*How do the planning processes of Brisbane and Singapore contribute to their development of flood risk* *management approaches?*' and Research Question 3 '*How, and to what extent, can blue-green infrastructure be used as a more resilient and sustainable option for flood risk management and what are the barriers to the implementation of this infrastructure?'*

Section 6.1 will present Australia's national level responses to flood risk management; section 6.2 will address the Queensland Government's state level responses; and the last section will discuss the strategies of the Brisbane City Council (BCC) around flood risk management and BGI. These sections will sequentially demonstrate the broad focus at the national level to the specific focus at the local level, indicating the planning capacity and priorities each tier of government has around flood risk management and BGI. Additionally, specific examples of BGI implemented as a key flood risk management approach will be highlighted at the BCC and community level, demonstrating that there is more capacity for increased BGI applications when initiated and supported by the BCC and the community.

The chapter analyses the most relevant policy and planning documents at a range of scales. Table 6.1 below details the documents selected in relation to flood risk management and BGI for this analysis, with an overview provided by Figure 6.1 on the relationship of these documents.

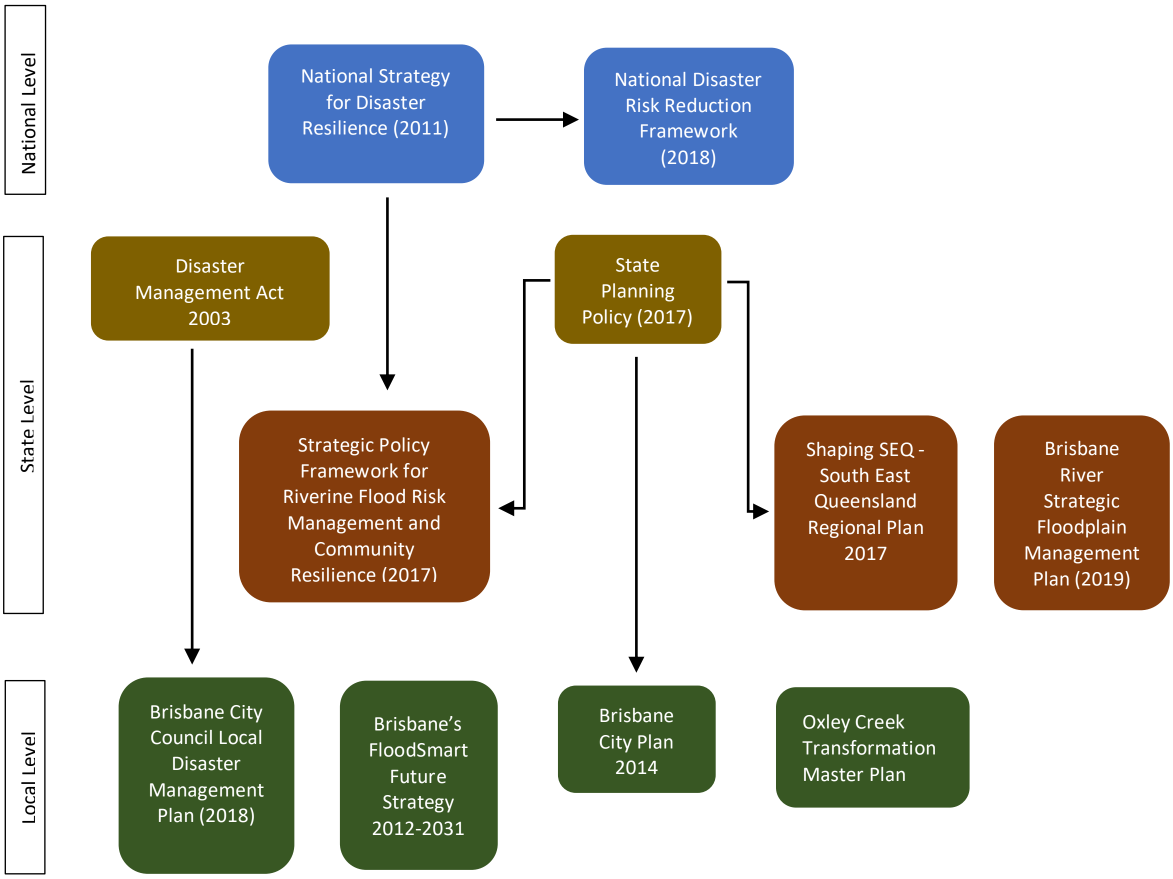
Table 6.1 *List of Planning and Policy Documents Selected for Brisbane.*

Australia – National Level	Queensland – State Level	Brisbane – Local Level
National Strategy for Disaster Resilience	Disaster Management Act 2003	Brisbane City Council Local Disaster Management Plan
National Disaster Risk Reduction Framework	State Planning Policy	Brisbane City Council 2014
	ShapingSEQ – South East Queensland Regional Plan 2017	Brisbane's FloodSmart Future Strategy 2012-2031
	Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience	Oxley Creek Transformation Master Plan

	Brisbane River Strategic Floodplain Management Plan

Note. List of planning and policy documents relevant to flood risk management and Blue-Green Infrastructure that were selected for Brisbane.

Figure 6.1 *Overview of Planning and Policy Documents Selected for Brisbane.*



Note. An overview of the planning and policy documents relating to flood risk management in Brisbane. (Documents that do not have arrows are standalone documents at their respective levels).

Through Figure 6.1, it can be seen that the Queensland Government and the BCC has more focus and responsibilities around flood risk management compared to the Australian Government, reflecting the institutional structure as mentioned in Chapter 4 (Brisbane Context).

There is an overlap of content with the number of documents at the state level which will be addressed in section 6.4 of this chapter and Chapter 7, with some uncertainty around the implementation of approaches as some documents guide strategic thinking rather than function as statutory documents. Some documents (without arrows) are also standalone documents that have been developed to address a gap in planning and complement the existing documents. Opportunities for catchment planning have been identified at the state level, however due to overlapping content and the varied dissemination of responsibilities to other agencies, a whole-of-catchment approach may be challenging as agencies need a clearer vision and integrated approach for actions. At the local level, there is better distinction of responsibilities and targeted approaches to the different areas of flood risk management.

6.1 Australia's National Level Responses

6.1.1 National Strategy for Disaster Resilience

The National Strategy for Disaster Resilience (hereafter, the Strategy) is a national resilience strategy that works towards providing guidelines for disaster management for all levels of government, businesses, non-profit organisations and community decision-makers. The occurrence of 2010 – 2011 floods in the states of Queensland, New South Wales and Victoria, led to the official uptake and endorsement of the Strategy (Box *et al.*, 2013). The Strategy aims to enhance resilience for communities against disasters and emphasises that disaster resilience "is a shared responsibility for individuals, households, businesses and communities, as well as for governments" (Council of Australian Governments, 2011, p. iii). Primarily addressing disasters from the perspective of natural hazards, the Strategy calls for "an integrated, whole-of-nation effort" (Council of Australian Governments, 2011, p. 2) and can be seen to use a risk-oriented and socially-responsible approach towards enhancing disaster resilience through its strategic actions, including:

- Leading change and coordinating effort
- Understanding risks
- Communicating with and educating people about risks
- Partnering with those who effect change
- Empowering individuals and communities to exercise choice and take responsibility

- Supporting capabilities for disaster resilience
- Reducing risks in the built environment (Council of Australian Governments, 2011)

Through the strategic actions, the Strategy wants decision-makers in all sectors of society to be risk-aware and implement resilience within planning frameworks, provide resources towards planning for resilience and managing disaster risks, supply public information about reducing risks and building knowledge (Council of Australian Governments, 2011). The Strategy also intends for the provision of specific risk data catered to different members of the community and enhancing the knowledge of communities on actions at an individual level measures. The stated goal of 'Empowering individuals and communities to exercise choice and take responsibility', addresses planning in more detail: land use planning, building regulations and developments should consider the risks to all environments and avoid as much as possible developing in hazard-prone areas, have frequent revisions to regulations, include natural hazard management theories in higher level education and occupational training, and restoring buildings to more structurally-robust levels (Council of Australian Governments, 2011).

Summary

At the national level, the Strategy as a whole looks to provide guidance to decision-makers on enhancing disaster resilience using a risk-aware approach. Flood risk management is not explicitly mentioned within this strategy, rather it is alluded to under the collective category of natural hazards and is encompassed within the broad terminology of striving for disaster resilience. As part of improving disaster resilience, the Strategy encourages better risk awareness at all levels of society in addition to public dissemination of statistics around risks to increase information transparency. However, the Strategy does not provide detailed guidance on how this is to be achieved. It does provide some general guidance on actions that can be undertaken during planning through the goal of 'Empowering individuals and communities to exercise choice and take responsibility' that primarily works to improve risk awareness while alleviating risks. Having a whole-of-nation approach, the Strategy is intended to be broadly applicable to all levels of governments across Australia, businesses and non-governmental organisations. The Strategy has a good direction, but could include more specific guidance to all levels of decision-makers around increasing disaster resilience, including to floods. The next section will demonstrate a national framework that builds upon the Strategy's strategic approach to provide more information around reducing natural hazard risks, including flood risks.

6.1.2 National Disaster Risk Reduction Framework

The federal government acknowledges Australia's adoption of the Sendai Framework for Disaster Risk Reduction 2015 – 2030 (hereafter, the Sendai Framework), the Paris Agreement and the 2030 Agenda for Sustainable Development in 2015, leading to the collaboration of every state, territory, local government and private sector stakeholders to contribute to the creation of the National Disaster Risk Reduction Framework (NDRRF) (Commonwealth of Australia, 2018). Building upon the efforts of the 2011 National Strategy for Disaster Resilience, the priorities of the Sendai Framework were incorporated and adapted in the development of the NDRRF to further improve Australia's abilities in resilience. The NDRRF hopes to improve the knowledge around disaster risk, build collaborative and coordinated partnerships across sectors, and extend the public's hazard resilience; it aims to deliver on its objectives from 2019 – 2023, followed by a review before its delivery is continued till 2030. (Commonwealth of Australia, 2018).

Within this policy, various natural hazards, including floods, are broadly addressed at a national level rather than provide specific flood risk management measures. The main motivations for the NDRRF are: the increasing occurrence and strength of natural hazards, the symbiotic relationship of essential services and infrastructure, the growing exposure and vulnerability to hazards, extensive impacts from disasters, the rising costs suffered from disasters and the ensuing ramifications on the financial sectors such as investments and banking (Commonwealth of Australia, 2018).

Similar to the National Strategy for Disaster Resilience, the NDRRF aims for a whole-of-nation strategy towards "proactively reducing disaster risk, now and into the future" (Commonwealth of Australia, 2018, p. 3), focusing on a holistic rather than instructive approach that is generally administered onto Australia's built, social, natural and economic environments. The NDRRF calls for a disaster risk-oriented mindset towards decision-making, noting that all modifications and developments to any part of society will affect the Australia's ability in managing disaster risks. Accountability and investments in disaster risk mitigation are also highly encouraged as part of its 2030 vision. The goals of the NDRRF aim for mitigation actions, reducing risk through all decision-making and preparing decision-makers with the necessary resources for risk mitigation. The NDRRF's priorities focus on the following: understanding disaster risk; accountable decisions; enhanced investment; and governance, ownership and responsibility (Commonwealth of Australia, 2018). The federal government aims to work on these priorities and apply them across all sectors and levels of government towards informing plans, policies, risk and vulnerability assessments, technology development, information dissemination and fostering connections amongst multiple sectors and communities. In particular, the NDRRF looks to inform decisions around areas such as public policies; land use, infrastructure and development planning, investment and expenditure; legislation; and resources and programmes (Commonwealth of Australia, 2018).

Summary

The NDRRF does not supply any prescriptive regulations pertaining to its applications nor any specific responsibilities towards flood risk management; rather, it provides overarching but detailed guidelines for decision-makers in all sectors to use and adapt towards contributing to this whole-of-nation approach on managing and alleviating disaster risk. This includes everyone from the individual and community level, to non-profit organisations, businesses and governments. Similar to the 2011 National Strategy for Disaster Resilience, it does not explicitly refer to flood risks or flood risk management, rather these are categorised under natural hazards.

The NDRRF does however, provide more detail for decision-makers around the various principles that underpin the framework, the priorities adapted from the Sendai Framework and the strategies developed which would be helpful in supporting future actions undertaken for disaster resilience at all levels of society and for all sectors. A national implementation plan for the NDRRF was due to be issued in 2019 however, this has not yet been released and as such, the aspirations embodied within the Framework are yet to be translated and accompanied by a concrete plan for its implementation.

6.2 Queensland Government's Responses

6.2.1 Disaster Management Act 2003

The Disaster Management Act (DMA) 2003, current as of 25 May 2020, is Queensland's main legislation for disaster management and provides the foundations towards managing the State Emergency Service. The DMA 2003's main purposes is defined as follows:

> *(a) to help communities—*
>
> > *(i) mitigate the potential adverse effects of an event; and*
> >
> > *(ii) prepare for managing the effects of an event; and*
> >
> > *(iii) effectively respond to, and recover from, a disaster or an emergency situation;*
>
> *(b) to provide for effective disaster management for the State.*

(DMA 2003, s. 3)

Section 4 shares the provisions to which the purposes of the DMA are to be accomplished by:

> *(a) establishing disaster management groups for the State, disaster districts and local government areas;*
>
> *(b) preparing disaster management plans and guidelines;*
>
> *(c) ensuring communities receive appropriate information about preparing for, responding to and recovering from a disaster;*
>
> *(d) declaring a disaster situation;*
>
> *(e) establishing the Office of the Inspector-General of Emergency Management.*

(DMA 2003, s. 4)

The DMA 2003 defines disaster as "a serious disruption in a community, caused by the impact of an event, that requires a significant coordinated response by the state and other entities to help the community recover from the disruption" (s. 13), wherein such events cover non-environmental and naturally-occurring environmental events such as storms, storm tides and floods. In the same vein, disaster management is described as "arrangements about managing the potential adverse effects of an event, including, for example, arrangements for mitigating, preventing, preparing for, responding to and recovering from a disaster" (DMA 2003, s. 14). Flood risk management can therefore be deemed within this act as a type of disaster management. Additionally, the definition of disaster management provided by the DMA 2003 includes prevention, which is clarified as preventive measures.

Disaster management functions and powers of various levels of state government are designated by the DMA 2003 and are listed in hierarchical order from highest to lowest: state disaster management groups and committees are to undertake policy development and management strategies; district disaster management groups are to generate and administer district disaster management plans and operations; and local government disaster management groups are to develop disaster management frameworks and local disaster management plans. The DMA 2003 also covers the requirements for a comprehensive state disaster management plan, district disaster management plan, local government disaster management plan; all of which are to include a strategic policy framework, strategies, priorities and designated responsibilities of stakeholders involved.

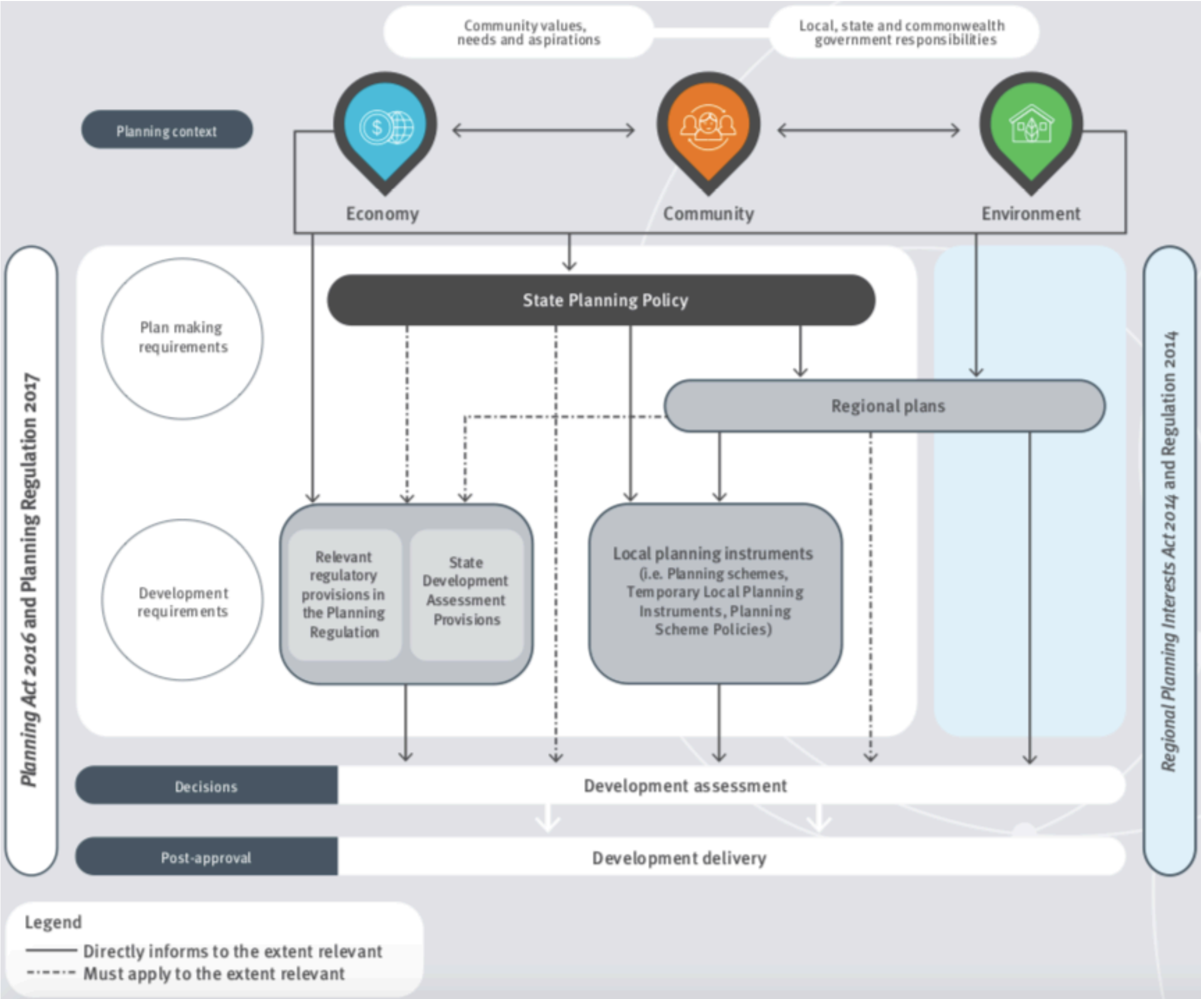
Summary

Overall, the DMA 2003 provides general legislative foundation for the state and local governments and government agencies to structure their disaster management framework and mandates the planning and policy documents that will inform actions towards averting, preparing, alleviating and responding to disasters. Floods are referred to under the DMA 2003, however, it considers floods under disasters, similar to the National Strategy for Disaster Resilience and the National Disaster Risk Reduction Framework. The DMA 2003, does identify mitigation, prevention, preparation and recovery as actions to address disaster management which are similar to the broad flood risk management strategies, as described in the literature review. The DMA 2003 is more prescriptive in the functions of disaster management and responsibilities of decision-makers, performing a more managerial role rather than providing specific direction on managing disasters, including floods. Additionally, more clarity is needed in the DMA 2003 to help streamline scopes around state and local planning and policy documents due to the range of such documents arising every few years and especially after a disaster event.

6.2.2 State Planning Policy

The Department of Infrastructure, Local Government and Planning (DILGP) (2017a) states that the State Planning Policy (SPP) is an integral segment within Queensland's planning system that communicates "the State's interests around land use planning and development" (p. 3). The SPP aligns with the Planning Act 2016 by presenting the interests of the State on plans and policies, one of which are "natural hazards, risk and resilience" (p. 4), which are to be addressed through the planning frameworks of local governments, and delivers towards disaster risk reduction under Resilient Queensland – The Queensland Strategy for Disaster Resilience 2018–2021 (DILGP, 2017a). This process is shown in Figure 6.2.

Figure 6.2 *State Planning Policy in the Queensland's Planning Framework*



Note. Overview of how the Queensland's State Planning Policy impacts regional and local plans (image source: Department of Infrastructure, Local Government and Planning, 2017a, p. 4).

Flooding is considered as part of natural hazards under the SPP, where an evidence-based risk management approach is advocated when planning for hazards (DILGPa, 2017). The State's DILGP aims for the Queensland's planning system to comprehensively incorporate natural hazards measures that will alleviate risks and strengthen public resilience; this is done through land use planning provisions, building controls, various flood risk management infrastructure and strategies. Specific policies addressing natural hazard risks, and hence flood risks, are provided in the SPP for incorporation into applicable planning frameworks: including risk assessments, discouraging development in hazard-prone areas or having measures to alleviate risks, development activities should not cause elevated exposure to hazards, and development should preserve existing natural features that assist in alleviating risks.

For local planning schemes that have not adequately incorporated the SPP, assessment benchmarks are provided for development applications that aim to build in flood-prone areas, which are similar to the policies addressing natural hazard risks. Stormwater management design objectives in the SPP also specify that flooding features outside developments should not exceed a 1% annual exceedance probability (AEP) (DILGPa, 2017). These policies primarily feature flood risk prevention strategies of land use planning, building regulations and codes, which were described in Chapter 2 (literature review).

Summary

The SPP primarily functions as a state planning tool that communicates the State's interests to other regional and local planning instruments. Similar to the previous planning documents, it regards floods under the rubric of natural hazards. The statutory effect of the SPP applies in the areas of developing and changing planning instruments, during assessments of development applications and during site designation for infrastructure. In the case of flooding, these areas must consider and integrate policies that will circumvent or alleviate flood risks in the outcomes where applicable. The SPP's policies pertaining to flood risks can be perceived as a flood risk prevention strategy through regulating land use and development, but these policies do not appear to be overly prescriptive as it allows decision-makers of other regional and local planning instruments to determine the areas of relevant application. The policies also suggest that a level of interpretation is allowed for, so that decision-makers can determine how development is to circumvent or alleviate flood risks, as they are bundled with other natural hazards.

6.2.3 ShapingSEQ - South East Queensland Regional Plan 2017

While the SPP is applicable throughout different parts of Queensland, there are also policies and plans that are specific to the geographic area focused upon in this thesis. The ShapingSEQ – South East Queensland Regional Plan 2017 (ShapingSEQ) was developed by the Queensland Government to provide guidance on the development of the South East Queensland region and planning undertaken by its local councils. The planning schemes of local governments are obligated to deliver towards the objectives of ShapingSEQ, while businesses, the community and institutions are encouraged to deliver on the ShapingSEQ in their own capacity such as through engagement, planning, resource management and research (DILGP, 2017b). Within the Queensland planning framework, ShapingSEQ develops the elements of the State Planning Policy (SPP) into broader themes and strategies to achieve the implementation of the state's interests in this specific geographical area (DILGP, 2017b).

A range of sectors are addressed within the ShapingSEQ such as, infrastructure planning, biodiversity, climate change, disaster resilience, land use and urban growth. ShapingSEQ's 'Goal 4: Sustain' recognises the importance of South East Queensland's biodiversity, ecological and environmental features and impacts of the growing population and urban pressure and acknowledges the imperative to increase environmental resilience (DILGP, 2017b). 'Element 5: Water sensitive communities' and 'Element 10: Safety' advocate for BGI strategies to assist in achieving Goal 4, along with managing flood risks. 'Goal 5: Live' focuses more on improving designs of places and considers that urban greening provides diverse benefits, which includes regulating the amount and quality of stormwater (DILGP, 2017b). Specific strategies relating to BGI and flood risk management are outlined in Table 6.2.

Table 6.2 *Blue-Green Infrastructure Strategies in ShapingSEQ*

Goals	Elements	Strategies
Goal 4: Sustain	**Element 5: Water sensitive communities** Water management in SEQ will use innovative approaches in urban, rural and natural areas to enhance and protect the health of waterways, wetlands, coast and bays.	Protect and sustainably manage the region's catchments to ensure the quality and quantity of water in our waterways, aquifers, wetlands, estuaries … meets the needs of the environment, industry and community.
		Plan for a water sensitive region by supporting innovation in water cycle management that increases the efficient use of water, security of supply, addresses climate change and manages impacts on waterways and Moreton Bay.

	Element 10: Safety Communities are designed and equipped to be safe, hazard-resilient places.	Maintain and improve natural assets that can mitigate risks associated with natural processes, and hazards such as flooding, salinity, landslide and bushfire.
		Use disaster risk management planning and adaptation strategies (such as the Queensland Strategy for Disaster Resilience), and avoidance of exposure to high-risk areas to minimise SEQ's vulnerability to development constraints and natural hazards.
Goal 5: Live	**Element 4: Working with natural systems** The liveability and sustainability of SEQ's urban environments are enhanced by incorporating urban greening networks.	Conserve and protect significant trees, plants of scale and significant species, as valuable community assets and use these features to enhance local character.
		Use extensive native vegetation and large shade trees in public spaces and along streets to encourage walking and cycling, and comfortable use of the outdoors.
		Work with the region's landscapes and waterways to deal with water management and urban heat island effects sustainably, provide urban-scale recreational resources and support small-scale urban food production by residents.

Table 6.2. BGI strategies outlined within the ShapingSEQ – South East Queensland Regional Plan 2017 in relation to managing flood risks (content source: Department of Infrastructure, Local Government and Planning, 2017b, pp. 82 – 94).

As well as the sectors outlined above, the ShapingSEQ also defines a regional growth pattern to guide all areas of urban growth and the preservation of natural areas, which considers the management of flood risk. This is under the 'Regional Landscape and Rural Production area', which includes the protection of natural water soaks, catchments, wetlands, mangroves, and forests; and the 'Urban Footprint', which determines the land needed to facilitate development and land that needs to be preserved such as areas at risk of floods (DILGP, 2017b). Through an implementation program to achieve the ShapingSEQ's goals and strategies, the 'Natural

Hazard Management (flood risk)' category describes actions for flood risk management through plan preparation and strategy development for the Brisbane River catchment, which will be facilitated by state and local governments, state-associated organisations and infrastructure suppliers. Under 'A water sensitive region' category, research on BGI principles for catchment management, strategy development and applications will be undertaken by the Cooperative Research Centre for Water Sensitive Cities.

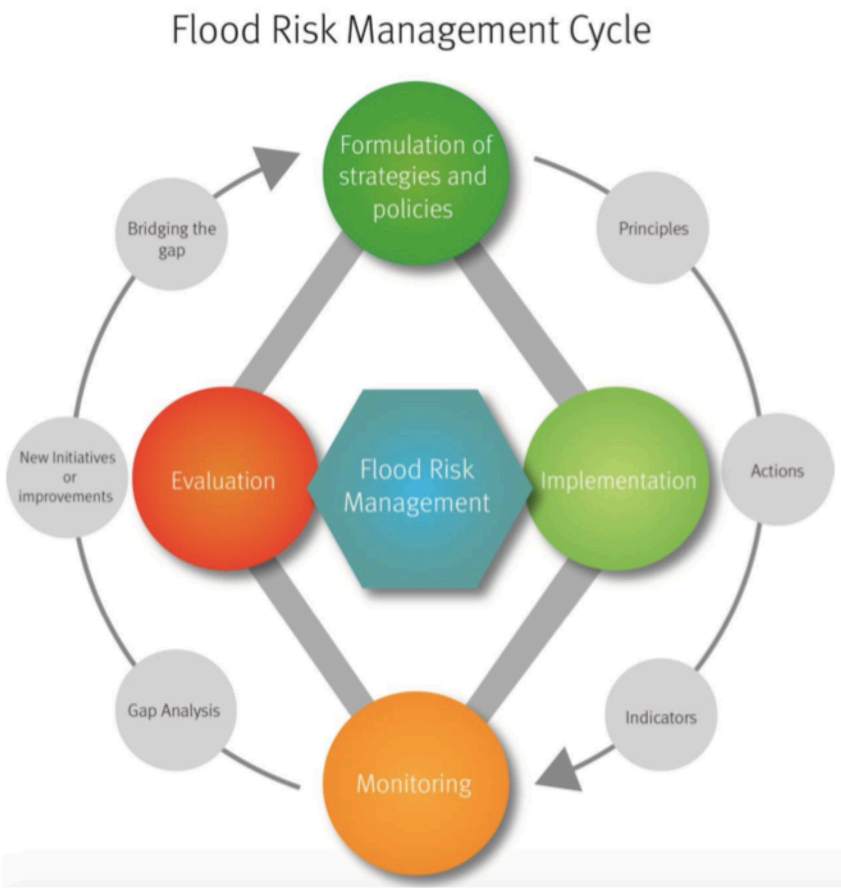
Summary

ShapingSEQ functions as a regional planning framework that expands upon the State Planning Policy, focusing on planning for South-East Queensland's land use while also considering the management of natural hazards and the use of BGI. The strategies identify targeted areas to guide local governments, businesses, institutions and communities towards delivering towards more innovative water management, increased hazard resilience, and embracing and utilising the functions of natural systems to improve sustainability. While ShapingSEQ can be seen to encourage the use of BGI to help manage the volume of stormwater and providing a range of other benefits, it does not provide much detail on how that would be achieved. The plan does address flood risk management to a limited extent through the flood risk prevention strategy of land use planning, which are to be carried out by state and local governments and organisations, of which notably, the Brisbane River Strategic Floodplain Management Plan has been released. In recognising that flooding is a common natural hazard in South East Queensland, ShapingSEQ could arguably include more strategies and details on flood risk management to guide state and local decision-makers on implementing measures.

6.2.4 Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience

The Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience (SPF) was developed by the authority for Queensland's disaster resilience and recovery, the Queensland Reconstruction Authority (QRA) (2019). The SPF guides the Queensland state in riverine flood risk management and supplies the strategic orientation for state government policies (Queensland Reconstruction Authority, 2017b). The SPF contributes to the *National Strategy for Disaster Resilience* (section 6.1.1), *State Planning Policy* (section 6.2.2) and *Resilient Queensland – The Queensland Strategy for Disaster Resilience 2018-2021*. The SPF also aligns with the following legislation: *DMA 2003* (section 6.2.1), *Sustainable Planning Act 2009* (now repealed), *Planning Act 2016*, *Water Act 2007*. Other forms of flooding are not examined within the SPF due to the priority given to riverine flooding; they are instead addressed in other state programmes. The SPF's stated aim is to provide a "comprehensive, multi-disciplinary flood risk management approach to the strategic management of Queensland's floodplains" (QRA, 2017b, p.1), as shown in Figure 6.3.

Figure 6.3 *Flood Risk Management Approach.*



Note. The Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience approach to flood risk management (image source: Queensland Reconstruction Authority, 2017b, p. 2).

QRA's (2017b) policy development and implementation are based upon the following philosophies of the SPF's holistic flood risk management:

- the certainty of flooding;
- shared responsibility;
- disaster risk management informs decision-making;
- multi-disciplinary catchment approach;
- community-led programmes;
- transparent dissemination of information.

Aimed at stakeholders from all levels of society, government and sectors, the SPF emphasises that governance pathways are needed to facilitate partnerships, transparency is key in information sharing, and all hold various responsibilities around riverine flood risk management and disaster response (QRA, 2017b). The QRA (2017b; 2019a; 2019b) oversees and administers recovery, resilience and mitigation policies for disasters along with infrastructure reconstruction schemes, the Queensland Government directs the governance pathways and the federal government supplies national services that assist with flood risk management such as flood forecasting and alert systems. Local government are in charge of local flood risk management procedures and flood planning while the communities hold individual responsibilities through flood risk awareness and preparative measures (QRA, 2017b).

Summary

The SPF is a strategic document, like the National Strategy for Disaster Resilience and National Disaster Risk Reduction Framework, but it is targeted at the flood risk management of rivers within Queensland, setting out the overarching approach and reasonings towards effective riverine flood management within Queensland. The SPF also explores the specific responsibilities of all stakeholders at various levels of society, advocating for a holistic and comprehensive vision and collaborative efforts. It does not look towards providing any prescriptive regulations, instead it offers more detailed guidance branching from its philosophies for stakeholders to undertake. The SPF was to be accompanied by an implementation plan that delineates the methods of delivery for the SPF's main objectives;

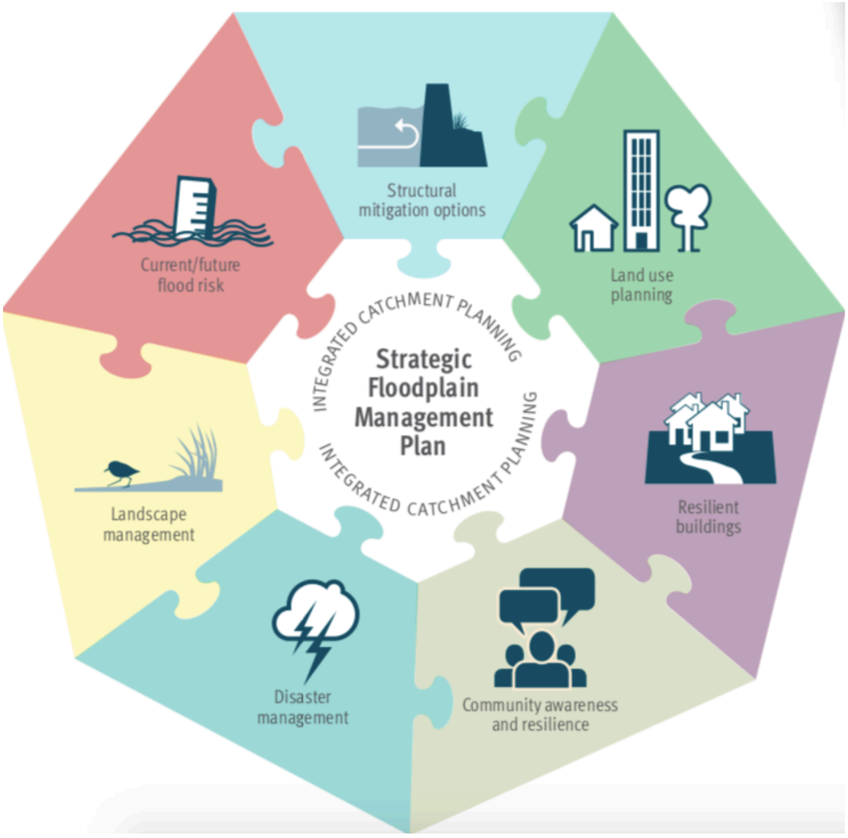
however, this has not yet been published. Hence, the SPF's objectives are yet to be translated into a tangible implementation plan by the QRA.

6.2.5 Brisbane River Strategic Floodplain Management Plan

Continuing from the state-wide Strategic Policy Framework (SPF), the QRA also has one regional catchment approach called the Brisbane River Catchment Flood Studies programme. The Brisbane River Strategic Floodplain Management Plan (hereafter, the Strategic Plan) provides a uniform direction towards regulating flood risk in the Brisbane River floodplain (QRA, 2019b). The Brisbane River Catchment Flood Study and the Strategic Plan was a collaborative effort between the Queensland Government, Seqwater (Queensland Government Bulk Water Supply Authority), the Brisbane City Council, Ipswich City Council, Somerset Regional Council (QRA, 2019b). The development of the Strategic Plan was based on the data within the Flood Study, guided by the National Strategy for Disaster Resilience and the Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience, and contains recommended actions for Queensland's local governments and the Queensland Government to administer, so as to improve the resilience of everyone inhabiting the Brisbane River floodplain against future floods (QRA, 2019b).

Flooding arising from the Brisbane and Bremer Rivers is the topical focus of the Strategic Plan, which uses "a holistic, integrated and collaborative approach" (p. 10) towards planning for flood risk (QRA, 2019c). It does this in respect to the wide-ranging and severe impacts suffered from the 2010-2011 floods and the areas of improvement highlighted by the QFCI, such as flood planning, development, building controls and essential services amongst others (QFCI, 2012). The specific areas considered within this integrated approach are shown in Figure 6.4.

Figure 6.4 Brisbane River Strategic Floodplain Management Plan's Approach



Note. The integrated multidisciplinary approach used by the Brisbane River Strategic Floodplain Management Plan for flood resilience (image source: Queensland Reconstruction Authority, 2019c, p. 12).

The Strategic Plan generates 9 desired outcomes (Table 6.3 below) that will contribute to flood risk management and support the continual management of the Brisbane River floodplain and the associated catchment. The integrated catchment approach (Figure 6.5 below) proposed by the Strategic Plan aims to provide cross-sector results through the planning processes, wherein BGI (known as WSUD in this approach) is considered through the sectors of landscape management, land use planning, and flood management.

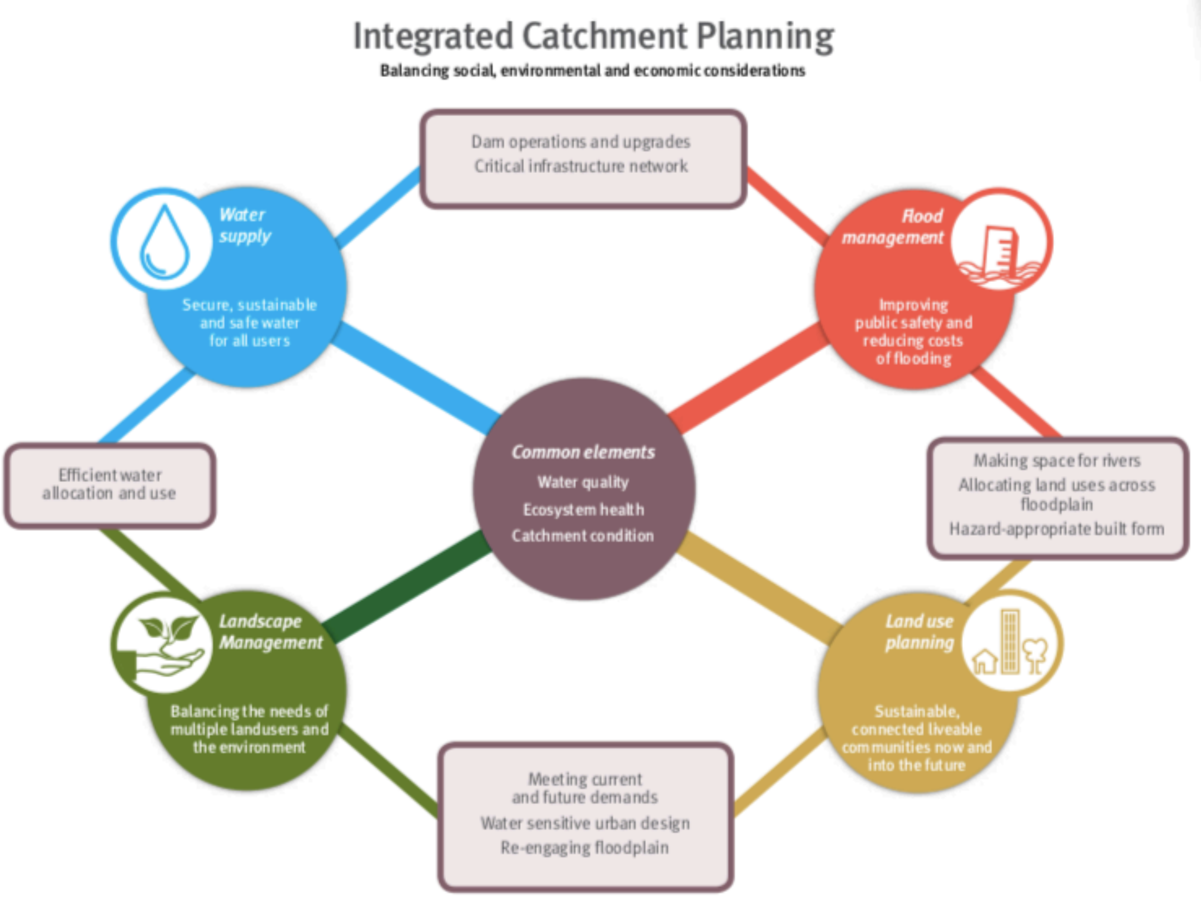
Table 6.3 Desired Outcomes to Flood Risk Management and Floodplain Management

1	Floodplain management initiatives are delivered using a holistic, integrated and collaborative approach.
2	Floodplain management initiatives are informed by a regional understanding of current flood risks

3	Future climate change impacts are recognised and planned for through adaptation and resilience building
4	Community awareness, understanding and response is the foundation for community resilience
5	Land use is planned, located and considers design elements to ensure development appropriately responds to the level of flood risk
6	Building design and construction improves community resilience and reduces property damages
7	Infrastructure is used to reduce flood risks where appropriate
8	Landscape management is planned across the catchment in a way that contributes to flood risk reduction
9	Disaster management planning and response applies a regionally consistent approach whilst recognising local flood risks

Note. The Brisbane River Strategic Floodplain Management Plan's desired outcomes towards flood risk management and floodplain management (content source: Queensland Reconstruction Authority, 2019c).

Figure 6.5 *Integrated Catchment Planning Approach*



Note. The Brisbane River Strategic Floodplain Management Plan's integrated catchment planning approach (image source: Queensland Reconstruction Authority, 2019c, p. 17).

Corresponding to the Strategic Plan's desired outcomes are a range of specific strategies to guide stakeholders when developing future regional flood risk strategies. These strategies revolve around the following priority areas of flood risk management and floodplain management namely:

- integrated catchment planning;
- knowledge sharing;
- climate change awareness;
- public availability of flood risk information;
- community engagement;
- accounting for flood risks in planning;
- flood-resilient developments;

- landscape management;
- context-specific flood risk information for the public and clear warning systems.

The strategies are applied to a set of proposed actions that are tagged to specific organisations to consider for future implementation, of which they are contingent on the organisations' individual priorities and available funding.

Summary

The Brisbane River Strategic Floodplain Management Plan functions as a strategic tool that was developed by various state and local authorities to help guide targeted efforts on managing flood risk within the Brisbane River floodplain. The Strategic Plan focuses on an integrated multidisciplinary approach that uses integrated catchment planning to deal with flood risks along with water supply, landscape management and land use planning. BGI principles such as WSUD and allowing rivers space to flow are highlighted as actions arising from these areas. However, not much information is provided on how these are to be achieved. Certainly, the Strategic Plan does instead provide detailed data and information on flood risks; through the integrated catchment planning approach, describes a range of detailed strategies that will deliver towards the Strategic Plan's outcomes. The Strategic Plan's broad range of priority areas indicate a deeper consideration and adaptation of flood risk management strategies within the Strategic Plan. As the relevant strategies and outcomes are to be achieved through a wide range of targeted actions that are tagged to different agencies for implementation, it suggests more thoughtful planning towards tackling issues and areas of improvement. However, the manifestation of these actions and thus the strategies, may experience delays as the Strategic Plan allows the relevant organisations the option of undertaking these actions depending on their priorities and funding capacities rather than requiring their implementation.

6.3 Brisbane City Council Responses

6.3.1 Brisbane City Council Local Disaster Management Plan

Following on from the Queensland Government's responses, this section onwards will now address the Brisbane City Council's (BCC) responses to flood risks. The BCC's Local Disaster Management Plan (LDMP) was developed in line with the DMA's Section 57 and 59 and the principles of Section 4A to provide overall disaster management guidance for the city of Brisbane (BCC, 2018). The BCC is mainly in charge of dealing with natural hazard disasters within Brisbane and are able to seek further higher-level government support through the Queensland Disaster Management Arrangement. The LDMP highlights floods as the predominant threat to the Brisbane community, and recognises that various types of flood types occur within the catchment; other natural hazards are also considered in the LDMP. The LDMP aims to alleviate risk, strengthen public resilience, provide suitable disaster response actions, and recovery actions after a disaster; this is summarised under the LDMP's approach of "prevention, preparedness, response, and recovery" (p. 14) along with short to long-term disaster support and partnerships across various agencies to build a support network (BCC, 2018).

In line with the Disaster Management Act 2003, the BCC (2018) provides planning and policies to its Local Disaster Management Group and conducts Brisbane's disaster management activities through its Local Disaster Management Group and Local Disaster Coordination Centre. Comprised of the BCC, state and local government bureaus, emergency services, non-profit organisations, and companies that provide infrastructure and services, the Local Disaster Management Group works with the Local Disaster Coordination Centre within a collaborative chain of command known as the Brisbane Incident Management System. According to the BCC, this system demonstrates the Council's "scalable and flexible response to emergency or disaster events" (BCC, 2018, p. 19) and allows task dissemination across various levels of management for more efficient responses (BCC, 2018). BCC's multi-faceted outlook towards managing hazard risk is defined in LDMP under the following strategy categories: land use planning and development control, infrastructure and asset management, disaster response, and education and awareness. Table 6.4 displays the various strategies relevant to flood risk management.

Table 6.4 Local Disaster Management Plan's Flood Risk Management Strategies.

Land use planning and development control	Infrastructure and asset management	Disaster response	Education and awareness
Brisbane City Plan 2014 with Natural Hazard overlays	Backflow prevention devices	Business continuity plans	Be Prepared for severe weather communication campaign
FloodWise Property Report	Flood mitigation infrastructure	BCC internal response procedures	Interactive Flood Awareness Map
Voluntary Home Purchase Scheme	Regular maintenance of infrastructure, sea and river walls	Equipped Local Disaster Coordination Centre	Disaster Management training and exercising
Lord Mayor's Task Force on Suburban Flooding	Flood-resilient design	Local Disaster Management Group	Community engagement activities
Building codes	Signage displaying risk		Community service announcements
	Stormwater infrastructure network		Early warning alert service
			Flooding in Brisbane guide

Note. Flood risk management-related strategies undertaken by the Brisbane City Council under the Local Disaster Management Plan (content source: Brisbane City Council, 2018).

The LDMP is a framework that provides an overview of Brisbane's many hazards, the BCC's disaster management approach, the responsibilities, the strategies used. Actions that the wider community can take to prepare for and respond to flooding are shared in the LDMP, these include general education and awareness strategies, staying notified of early warning alerts and announcements (by the Local Disaster Management Group, Local Disaster Coordination Centre and BCC's Early Warning Alert Service), and evacuation plans (BCC, 2018). The LDMP also details aspects and actions of the BCC for recovery, which includes financial aid, the restoration of the environment, and reconstruction of buildings, structures and infrastructure (BCC, 2018). It should be noted that the scope of the BCC disaster management department, the Local Disaster Management Group and Local Disaster Coordination Centre mainly encompass disaster response to hazard events and the preparation of the public, hence in terms of floods, not all areas of flood risk management are addressed within the LDMP.

Summary

The LDMP is a statutory document created according to the Disaster Management Act 2003 for Brisbane's disaster management, where floods are considered as the main disaster event in Brisbane amongst other disasters. It denotes the BCC's functions in conducting disaster management, and primarily aims to alleviate flood risk and increase resilience by ensuring people are ready, able to respond and recover from disasters. The LDMP also describes a wide range of flood risk management strategies developed by the BCC to control and alleviate flood risks, in addition to other disaster management approaches. It is a relatively straightforward and succinct plan that demonstrates the capabilities and capacity of the BCC to deal with disasters, wherein there is a good availability of known resources for people of different sectors to engage with in terms of preparing for and responding to floods.

6.3.2 Brisbane City Plan 2014

The Brisbane City Plan 2014 (hereafter, the Plan) is the BCC's (2014) current planning scheme that informs Brisbane City's land use, urban development, infrastructure, transport, hazards and environmental quality. The Plan is designed with a 20-year long-term outlook that also works towards achieving the themes in Brisbane Vision 2031, and now gives effect to the current Queensland Planning Act 2016 after the Sustainable Planning Act 2009 was repealed (BCC, 2014). The Brisbane City Plan 2014 recognises Brisbane's considerable risk of flooding and has integrated the State's interests around floods and flood risks in line with the State Planning Policy (SPP); it demonstrates BCC's flood risk management approach which is founded upon concepts of floodplain risk management (BCC, 2014). Due to the extensive amount of policy and planning information, the relevant tools used in BCC's flood risk management, their overall functions towards flood risk management will be summarised in Table 6.5.

__Table 6.5__ Relevant Brisbane City Plan 2014 Flood Risk Management Planning Instruments

Flood Risk Management Instruments	Summary of Functions
Section 1.7.2 Designated flood hazard area for Queensland Development Code MP3.5	In the Flood overlay map, any land classified under creek/waterways flood planning area sub-categories 1 – 4 and Brisbane river flood planning sub-categories 1 – 4, is a 'designated flood hazard area'.
Section 4.4 Desired standards of service for stormwater network'	Under Part 4 Local government infrastructure plan, Section 4.4 provides the performance standards for operating the stormwater network, which includes collection of stormwater flows and management of overland flow paths and waterway corridors to regulate and reduce flood risk.
Section 5.10 Categories of development and assessment – Overlay Table 5.10.11 Flood overlay	The flood overlay modifies 'the categories of development or assessment from that stated in a zone or neighbourhood plan and the relevant identified requirements and assessment benchmarks.'
Section 8.2.11 Flood overlay code	• The code is used to evaluate development in the Flood overlay and to administer the Strategic framework's policy direction. • Defines the categories of land in the Flood overlay and displayed on the Flood overlay map (Brisbane River flood planning area sub-categories 1-5, creek/water flood planning area sub-categories 1-5 and overland flow flood planning area sub-category) • Defines the development and performance outcomes, flood planning levels for developments at risk of flooding from river, creek or overland flow flooding to assess development against.

	• Defines 'land use compatibility with flood hazard'
SC6.7 'Compensatory earthworks planning scheme policy'	• Provides guidance on and standards for 'reshaping of land within a waterway corridor or in the creek/waterway flood planning area 1, 2 or 3 sub-categories within the Flood overlay, if contained within the 5% AEP flood extent of any creek, waterway for which no waterway corridor has been mapped'. • For a development application, BCC may require specific information that is provided in this policy. • Provides guidance on the standards for assessment benchmarks and direction on fulfilling these benchmarks.
SC6.11 'Flood planning scheme policy'	• Provides detailed information, guidance and particular design standards to aid in the outcomes of the Flood overlay code, the Coastal hazard overlay code and the Critical infrastructure and movement network overlay code. • This policy covers information on flood elements, lot boundaries flood overlay code flood planning areas, road services, flood risk assessments, flood studies, earthworks in floodplain. • For a development application, BCC may require specific information that is provided in this policy. • Provides guidance on the standards for assessment benchmarks and direction on fulfilling these benchmarks.

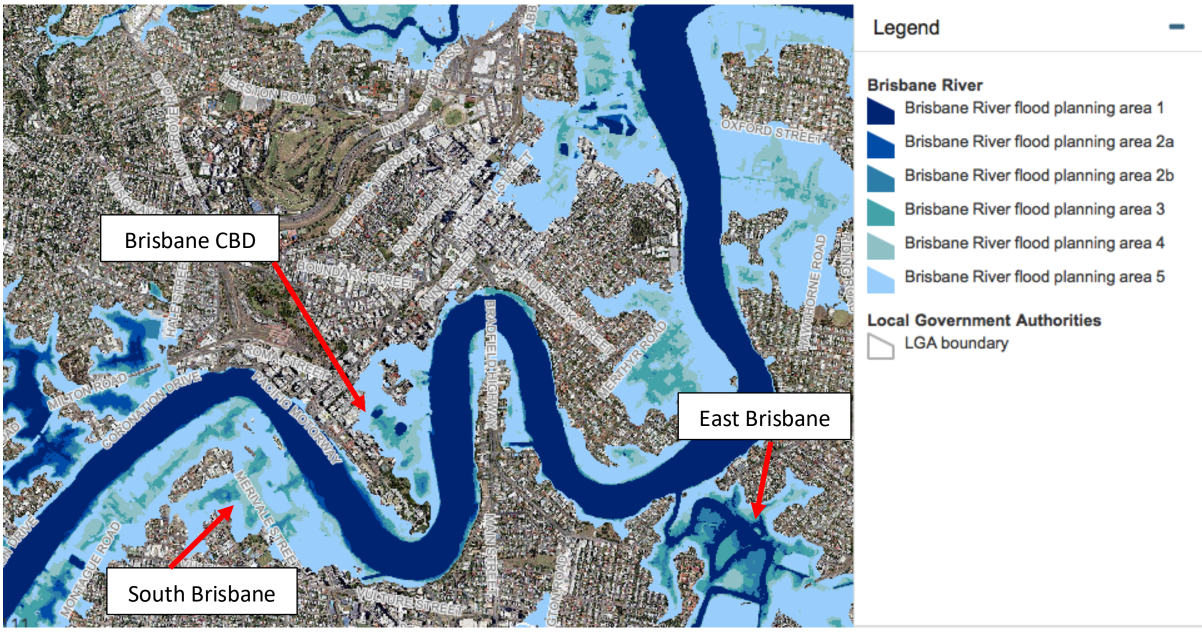
9.4.9 Stormwater Code	• The code is used to evaluate development suitability with regards to stormwater. • Development outcomes include, but not limited to, managing stormwater flows and reducing run-off. • Performance outcomes for development include, but is not limited to: minimising flooding; reducing harmful effects of stormwater management system and development on drainage and flooding; having adequate capacity in the system to transport run-off; providing for stormwater infrastructure in a catchment; adequate maintenance given to stormwater infrastructure; managing soil stability, erosion and sedimentation (relevant outcomes: PO1, PO4, PO10, PO11, PO13, PO14). • Flood planning levels are provided for developments and infrastructure at risk of flooding

Note. Summary of Brisbane City Plan 2014's main planning instruments that are relevant to flood risk management, and their functions (content adapted from Brisbane City Council, 2014).

The table above demonstrates that the Plan covers a large range of the aspects of flood risk management. As flooding is a major hazard in Brisbane, other planning provisions that mainly guide development also aim to avoid or mitigate any contribution to flooding. There are several Sections within the Plan that have some focus upon development outcomes that prevents development on land that is flood-prone or has drainage issues or restricts development to only allow functions that will assist in reducing likely off-site flood impacts. These include the 'Open space zone code' (section 6.2.3.2), 'Low impact industry zone code' (section 6.2.5.1), 'Industry zone code' (section 9.3.12), 'Special industry zone code' (section 6.2.5.3), 'Industry investigation zone code' (section 6.2.5.4) (BCC, 2014). Flooding is addressed in the 'Dwelling house code' for general and small lots (section 9.3.7 and 9.3.8), where dwellings need to avoid harmful effects on drainage or contribution to flooding at any point of the watercourse or neighbouring areas; the 'Infrastructure design code' (section 9.4.4), where culverts supplied with developments need to minimise any unfavourable consequences to water flow, water levels or flood patterns (BCC, 2014). Flooding and its risks are regularly referred in the Plan with extensive consideration given to managing flood risk and development in various planning tools.

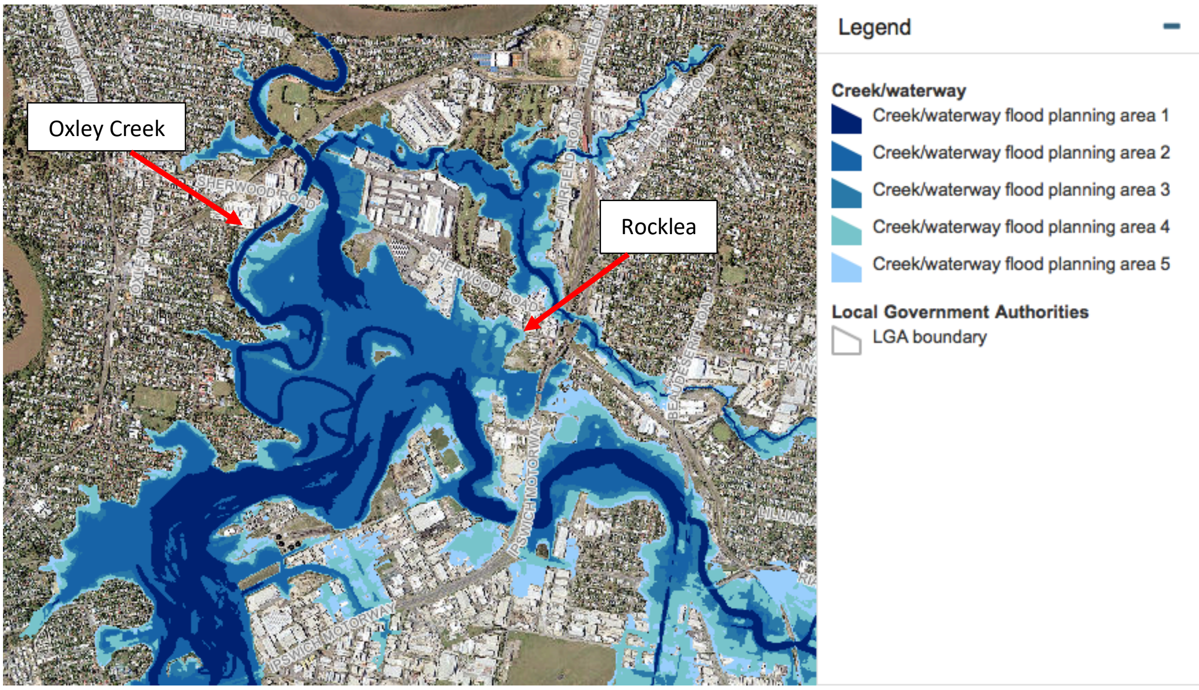
The Brisbane City Plan 2014's Map contains overlays of Brisbane's hazards, where the river, creek/waterway and overland flow flooding are areas of focus for this research; The 'Flood overlay' lists each flood type and their sub-categories and maps the land at risk accordingly to these categorisations. Examples of the flood mapping are seen in Figure 6.6 (Brisbane River flooding), Figure 6.7 (Creek/waterway flooding), Figure 6.8 (Overland flow flooding).

Figure 6.6 *Example of Brisbane River Flood Planning Areas.*



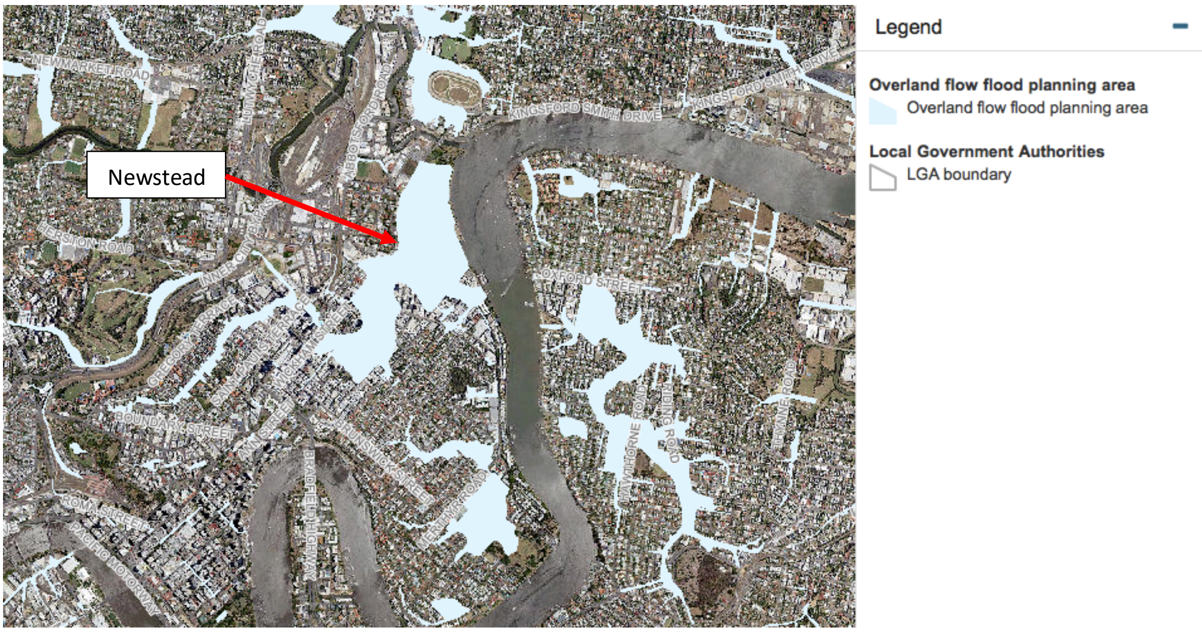
Note. Example of Brisbane River flood planning areas (Brisbane CBD, South and East Brisbane suburbs) in the Flood overlay in the Brisbane City Plan 2014 Map (image adapted from Brisbane City Council, 2020b).

Figure 6.7 Example of Creek/Waterway Flood Planning Areas.



Note. Example of creek/waterway flood planning areas (Oxley Creek and suburb of Rocklea) in the Flood overlay in the Brisbane City Plan 2014 Map (image adapted from Brisbane City Council, 2020b).

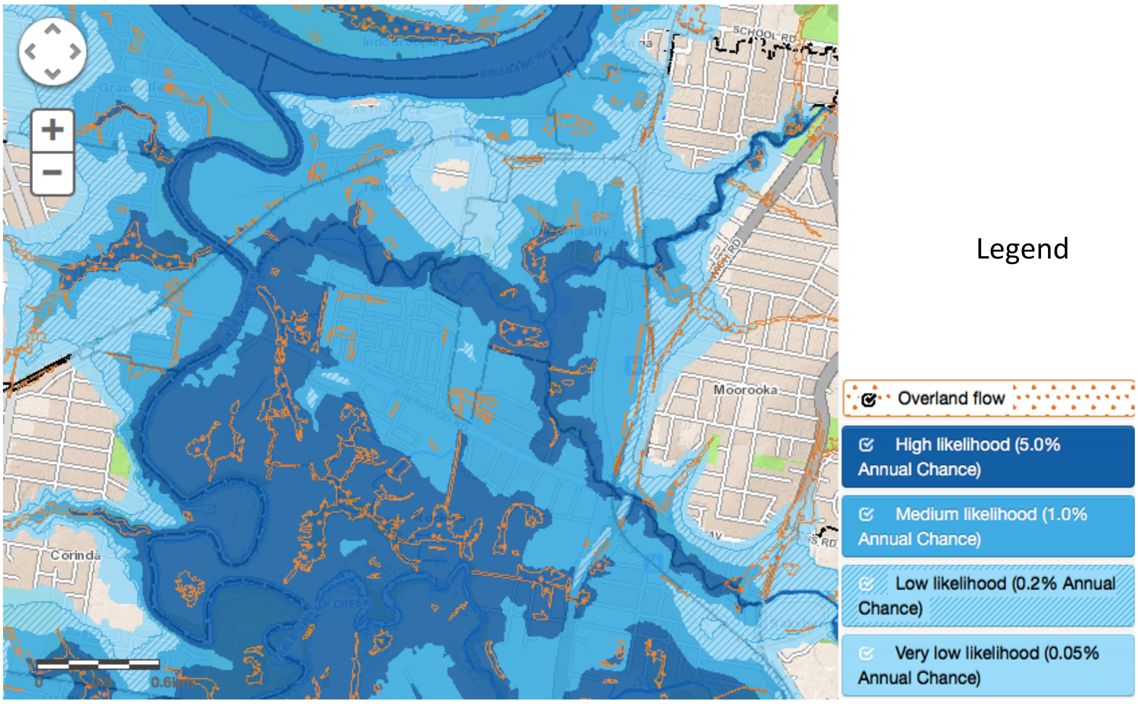
Figure 6.8 Example of Overland Flow Flood Planning Areas



Note. Example of Overland flow flood planning areas (Newstead, Brisbane) in the Flood overlay in the Brisbane City Plan 2014 Map (image adapted from Brisbane City Council, 2020b).

The BCC also provides a Flood Awareness Map that allows the public to better understand and locate areas at risk of floods. The Flood Awareness Map uses data from the most recent flood modelling, the *2017 Citywide Creek and Overland Flow Path Study* (BCC, 2020c) and categorises areas at risk by high, medium, low and very low likelihood to provide a gauge of the likelihood of flooding from water sources; this is shown in Figure 6.9.

Figure 6.9 *Example of Brisbane City Council's Flood Awareness Map.*



Note. Example of the varying likelihood levels of flooding in Oxley Creek and the suburb of Rocklea on the Brisbane City Council's Flood Awareness Map (image adapted from Brisbane City Council, 2020c).

Principles of BGI that aid in managing flood risk are embedded within the Brisbane City Plan 2014's planning tools for development. Due to the extensive amount of policy and planning information, an adapted summary of the relevant tools and their functions is shown below in is shown in Table 6.6. The development instruments listed here guide development within waterway corridors and wetlands, and stormwater regulation.

***Table 6.6** Brisbane City Plan 2014's Blue-Green Infrastructure Planning Instruments*

Development Instruments	Summary of Functions
8.2.26 Waterway corridors overlay code	• The code is used to evaluate development in the Waterway corridors overlay and to administer the Strategic framework's policy direction. • Section 8.2.26.2 - 'Development protects the flood storage and conveyance function of a waterway corridor.' • Performance outcomes for development in waterway corridor include, but not limited to: preserving the flow, filtration and infiltration ability of waterways; preventing waterway fragmentation, safeguarding riparian vegetation, measures to aid in waterway re-naturalisation.
8.2.27 Wetlands overlay code	• The code is used to evaluate development in the Wetlands overlay and to administer the Strategic framework's policy direction. • Development outcomes aim to maintain hydrological and ecological functions of wetlands. • Performance outcomes for development in wetlands include preserving flood storage function, and reducing, as much as possible, any harmful modifications to hydrological patterns.
9.4.9 Stormwater Code	• The code is used to evaluate development suitability with regards to stormwater. • Development outcomes include, but not limited to, using water-sensitive urban design principles to regulate stormwater run-off quantity and quality, and a stormwater system that reduces adverse impacts to natural catchment hydrological processes.

	• Performance outcomes for development provides for stormwater management systems that include, but not limited to, maximising water sensitive urban design, using natural waterway corridors and natural channel design principles, ecologically-conscious design of stormwater systems, reducing impervious surfaces and collecting runoff for reuse (relevant outcomes: PO1, PO2, PO5, PO8, PO9).
SC6.16 Infrastructure design planning scheme policy – Chapter 7 Stormwater drainage	• Provides detailed information, guidance and particular design standards for stormwater drainage to alleviate flooding but also uses water-sensitive urban design principles in the system. • This policy provides information that includes, but is not limited to: stormwater drainage system function and design standards, hydrology and hydraulics, types of drainage infrastructure used (swales, rain gardens, tree pits and tree trenches in addition to conventional grey infrastructure), stormwater detention and retention systems, road drainage and open channels, stormwater outlets.

Note. Summary of the Brisbane City Plan 2014's planning instruments for development which incorporate BGI principles to help in managing flood risk (content adapted from BCC, 2014).

Summary

The Brisbane City Plan 2014 is a comprehensive planning scheme that covers various sectors around land use and development. Flooding in particular is addressed through detailed provisions to assess development applications against such as flood overlays, performance standards, assessment benchmarks, codes, as well as other provisions that limit developments to alleviate flood risk. The Flood Overlay Code provides the specific guidelines for developing in those areas to ensure that they are sensitive to the respective flood risks, rather than prevent future development in areas that flood. Arguably, this indicates that the BCC may permit development in such areas as long as the risks are professionally assessed, and planning controls are adhered to. The Plan's Map is a practical resource that visualises the areas of flood susceptibility identified under the flood overlay code to alert users of how floods could affect future development in those areas. Similarly, the Flood Awareness Map helps the public to identify areas that experience different levels and types of flood risks to assist in decisions such as evacuation routes, buying properties and developing land. However, despite their obvious usefulness, both Maps could benefit from having long-term indicators and mapping visualisations that show how the risks and susceptible areas have changed over time.

BGI principles appear to be quite well included in the Plan, in the form of provisions that regulate development to avoid or reduce impacts on the capacities of natural systems, to require developments to include water sensitive urban design (WSUD) design in regulating stormwater and detailed guidelines and standards for stormwater drainage to incorporate for BGI measures. The Plan demonstrates a significant integration of BGI principles (termed in the Plan as WSUD) to support development towards avoiding and minimising contribution to flooding, indicating the BCC's recognition of the ability for natural water systems to manage flood water, along with the inclusion of BGI principles in stormwater systems to upgrade their ability in managing stormwater and runoff.

6.3.3 Brisbane's FloodSmart Future Strategy 2012-2031

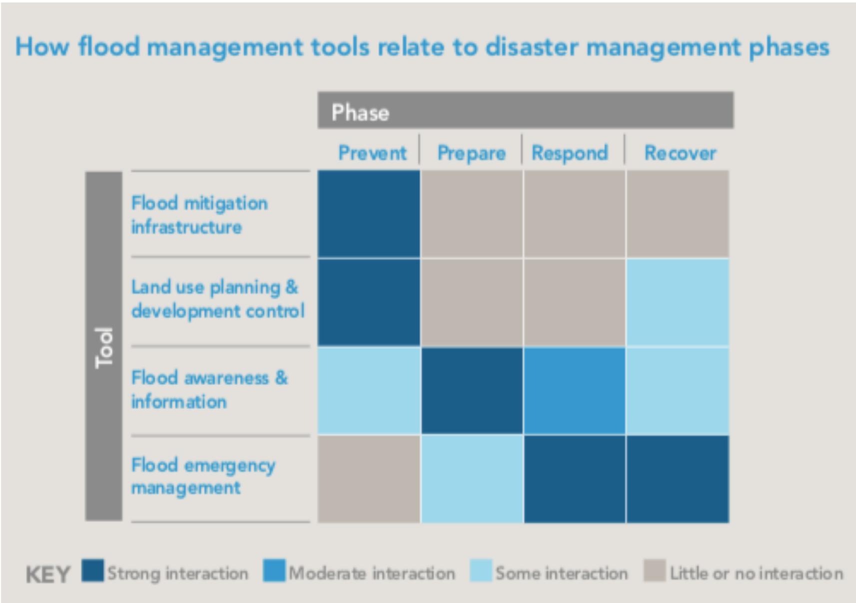
Brisbane's FloodSmart Future Strategy 2012-2031 (hereafter, the Strategy) replaces the Brisbane City Council January 2011 Flood Action Plan, which was closed on 31 October 2016 as the BCC has addressed all of the recommendations within the Flood Action Plan. The Strategy describes BCC's approach to flood risk management and aims to provide a consolidated network of instruments for flood risk management (BCC, 2013). The Strategy provides an overview of the various flood risk management measures already undertaken, such as the early warning alert service, Flood Awareness Map, Voluntary Home Purchase Scheme and FloodWise Property Report (BCC, 2013). Four principles underpin the Strategy:

- Protecting people's lives, property and wellbeing is a key priority.
- Balancing, social, economic and environmental objectives promotes the responsible development of the city appropriate to the risk of flooding.

- A long-term perspective of flooding provides both a consistent direction and flexibility to adapt to emerging hazards and opportunities.
- Integrated use of the flood risk management tools and working together with the community and agencies will achieve optimal outcomes (BCC, 2013a).

Flood risk management as defined within the Strategy "involves assessing and managing flood risks to reduce the impacts on people and property" (BCC, 2013a, p. 9). An integrated approach towards flood risk management is taken by the BCC, encompassing land use planning, flood mitigation infrastructure, flood information and flood emergency management, which in line with best practice for disaster management (BCC, 2013a); this is visualised in Figure 7.0.

Figure 6.10 *How Flood Management Tools Relate to Disaster Management Phases.*



Note. Brisbane City Council's flood risk management framework in relation to disaster management best practice (image source: Brisbane City Council, 2013a).

This integrated approach to flood risk management is applied to deliver the Strategy's strategic outcomes; these outcomes for flood risk management that the BCC will work towards are:

- A risk-based approach to flood management
- An integrated and adaptive approach
- Smart planning and building

- An educated and resilient community
- World-class response and recovery
- Well-maintained and improved structural assets (BCC, 2013a)

Summary

The FloodSmart Future Strategy 2012-2031 is a broad strategic document that describes the BCC's flood risk management approach and the various tools used after the 2011 floods to manage and alleviate flood risks. The integrated approach shared by the Strategy builds upon the four main phases of disaster management, which are to be addressed by the BCC's four types of flood risk management tools to achieve the Strategy's outcomes. Overall, the Strategy has a long-term and comprehensive strategic approach towards guiding BCC's flood risk management processes. Within this Strategy, it is clear that the BCC recognises the long-standing nature of the Brisbane River catchment and the Brisbane floodplain. Through this Strategy, the BCC aims to adopt a risk-based and flexible mindset works towards establishing a coordinated and integrated approach with the public and various stakeholders, along with public resilience, infrastructure improvements and effective flood response and recovery.

6.3.4 Oxley Creek Transformation Master Plan

The Oxley Creek Transformation (OCT) project is a $100 million 20-year project funded by the BCC towards reinvigorating the Oxley Creek corridor that extends from the Brisbane River, starting at Tennyson and ending at Larapinta, to provide various social, economic and environmental improvements that can benefit the environment and society (Oxley Creek Transformation, n.d.-a). Managed by a subsidiary company established in 2017 by the BCC to focus and streamline efforts, the project hopes other sustainable revenue streams can be attained through the revitalisation to sustain it into the future (OCT, n.d.-a; n.d.-b). The OCT project's main aims include increasing flood resilience, stormwater reuse and measures that contribute to environmental regeneration, reestablishment of wildlife habitats and expanding its green spaces (OCT, n.d.-b). Within the broader strategic intent of the OCT Master Plan, it aims to have a high level of community involvement in addition to the participation of the government, businesses and industry sectors; this section will provide an example of this.

The OCT Master Plan does not function as a statutory planning document, rather it proposes strategies for stakeholders that may stimulate modifications to current policies and rules, and future undertakings; these were supported and revised through stakeholder consultation (OCT, n.d.-b). The relevant parts of the OCT Master Plan are presented in Table 6.7.

Table 6.7 *Relevant Main Objectives of the Oxley Creek Transformation Master Plan*

Goals	Environment	Social/Community	Economic
Strategies	Environmental protection and enhancement	Connecting communities	Financial sustainability
	Flood preparedness and resilience	Character, identity and interpretation	Sustainable economic development
	Catchment, waterway and water management	Diverse experiences	Implementation and place management
	Water smart planning and design	Enterprising and innovative design and governance	Collaboration and partnership
Priority Projects	• The Greenway • Oxley Creek Common Bird Sanctuary	• Sustainable Economic Development Strategy • Nature-based Adventure Parkland	• Archerfield Wetlands Parkland and Interpretive Centre • Strategic Corridor Restoration Plan

Note. Overview of the relevant main objectives within the Oxley Creek Transformation Master Plan (content source: Oxley Creek Transformation, n.d.-b).

The OCT Master Plan manages flood risk through strategies that include planning and design with flood resilience in mind, providing community education on creek flooding, establishing flood risk information in signage, encouraging designs to use integrated design measures, and collaborating with experts and practitioners to generate WSUD measures (OCT, n.d.-b). The Plan's catchment and waterway management strategies also address flood risk through BGI-type measures such as creek stabilisation, revegetation, protection of riparian habitats, run-off collection and stormwater harvesting. Strategies for water smart planning and design in the Plan particularly identify exploration and utilisation of WSUD measures, water smart and green infrastructure that can provide various functions in addition to enhancing resilience to floods.

Following on from the Plan's strategies, strategic ideas identify areas of Oxley Creek where potential concepts might be implemented, of which six ideas have been chosen as priority projects to be actioned. The projects that especially consider management of flood risk using BGI-type measures are the Archerfield Wetlands and Interpretive Centre and Strategic Corridor Restoration Plan. Oxley Creek's current primary interest is to support the delivery of these priority projects through continued technical work and stakeholder and public engagement; however, the execution and success of these projects are dependent on financial resources and the fulfilment of other sub-schemes (OCT, n.d.-b).

Summary

The OCT Master Plan describes the vision, strategies and priority projects of the OCT Transformation Project, which aims to improve flood resilience along with providing other environmental benefits. Although not a statutory document, it provides a wide but comprehensive overview of the direction of the OCT Transformation Project. Having a range of smaller priority projects arising out of the OCT Master Plan is a practical and manageable way to target various areas within Oxley Creek corridor and working towards the continued delivery of the entire Project, particularly if there are constraints from funding and other priorities. A prominent feature of the Project is the incorporation of BGI principles (including WSUD) and its approach to actively involve the community and experts in its strategies and projects in developing measures that reduce flood risk while regenerating the catchment and provide other tourism and economic opportunities. This Project can be currently considered as Brisbane's most noteworthy long-term BGI initiative that has been community-driven and has garnered the support of BCC and other stakeholders, demonstrating an example of the future potential for similar projects to take root in Brisbane with the careful consideration of the funding, resources and prioritisation needed to ensure their success.

6.4 Concluding Discussion

This chapter introduces the relevant planning and policy documents at national, state and local levels that pertain to the planning processes of regulating flood risks, in addition to documents that incorporate BGI principles and measures for flood risk management. An evaluating summary is provided after each document to provide an overarching view of the document's purpose, highlight any strengths and issues and areas that could be improved. It was observed that national-level documents primarily focused on natural disasters as a collective category, wherein floods were addressed under this category, and shared broad frameworks that were applicable nation-wide. National-level documents could instead specify more detailed strategies or policies that can guide decision-makers on developing more informed strategies and actions for improved disaster resilience.

State-level documents, both statutory and non-statutory either categorised floods under the natural disasters or natural hazards category or had a targeted focus on floods. These documents generally provide more guidance around the functions and responsibilities of managing floods either exclusively or as part of a wider disaster management framework. Other documents are structured differently, such as ShapingSEQ, which offers broad strategies with a limited focus on flood risks but includes BGI as a flood risk management measure that also provides other environmental benefits, while the Brisbane River Strategic Floodplain Management Plan utilises an integrated catchment planning that incorporates BGI principles in addressing flood risks. Local level documents tended to provide more succinct and targeted information on the flood risk management approach, the range of strategies used, and the provisions for regulating developments and managing stormwater with BGI, and projects that are largely BGI-focused; this demonstrates a higher awareness and engagement around flood risks at the local level.

Overall, these planning and policy documents vary in prescriptiveness depending on their purpose, with several lacking more explicit information on how certain features of flood risk management and flood resilience is to be implemented. Similarly, some documents lack further guidance on ways that BGI is to be implemented for flood risk management, while others provide comprehensive strategies and provisions that indicate more consideration and planning towards improving the management of stormwater and flood risks. An overlap of information was noted across some state documents, hence further consideration would be needed to streamline their scopes so as to improve their functionality in planning for flood risks. The use of BGI is more notable at the local level, such as in plan provisions towards stormwater regulation and conservation of natural systems, while a major focus can be seen in community-driven project (OCT Transformation Project), indicating a growing interest and push for increased integration of natural systems and their functions within Brisbane's flood risk management, as well as to improve environmental health and overall liveability.

The following Chapter 7 will then assess in detail the various strategies and approaches used for flood risk management in Singapore, in particular approaches that focus on BGI as a core flood risk management strategy that integrates with the country's planning. Chapter 7 will also contain a comprehensive analysis comparing of the selected policy and planning approaches in Brisbane against those of Singapore in terms of flood risk management and BGI. This is to understand the various rationale for the way flood risk management is developed and conducted in both case studies and how BGI is implemented to help manage and mitigate flood risks.

7 Results – Singapore’s Planning and Policy Documents and Comparative Policy Analysis

This chapter follows on from the previous Chapter 6 to assess the planning and legislative environments of flood risk management and Blue-Green Infrastructure (BGI) practices in Singapore, to compare and contrast with that of Brisbane. This will be contextualised through an analysis of Singapore’s planning and policy documents which were selected based on their immediate influence and relevance on planning for flood risk management and BGI (in relation to regulating flood risks). For brevity, the research will only focus on flooding within urban areas (flash flooding) and exclude storm surges as the latter is categorised under coastal hazards. In contrast to the Brisbane, which has a tiered governance structure that affords various responsibilities to the different tiers of government, much of Singapore’s approach to managing flood risks is conducted through a centralised integrated stormwater management approach that works together with a national programme incorporating BGI-type strategies; these approaches will be further explored.

Section 7.1 – 7.4 will discuss the relevant planning and policy responses to flood risk management in Singapore, this comprises of legislative, statutory and non-statutory documents that solely address stormwater management or a mix of managing stormwater for flood risks and the implementation of BGI. Section 7.5 will then analyse all the flood risk management responses relevant to Brisbane (from the Chapter 6) and Singapore. As was foregrounded in the methodology chapter, this will be done through schemes created for flood risk management and BGI; the schemes' criteria were derived from the literature review generating five general strategies of flood risk management and six core areas of BGI that are key to the infrastructure's successful implementation. This analysis also includes an assessment of the level of BGI present in the planning and policy documents from both case studies to help determine the extent to which BGI is planned for and the capacity to which BGI can be further implemented in future. The documents selected for Singapore in relation to flood risk management and BGI are as follows:

- Sewerage and Drainage Act 2001
- Master Plan 2019
- Managing Stormwater for Our Future (2014) and Code of Practice on Surface Water Drainage
- Active, Beautiful, Clean Waters Programme: Water as An Environmental Asset

The information within this chapter will address Research Question 1 '*How do the planning processes of Brisbane and Singapore contribute to the development of urban flood management systems and strategies*?' and Research Question 3 '*How and to what extent can blue-green infrastructure be used as a more resilient and sustainable option for flood risk management and what are the barriers to the implementation of this infrastructure?*'

7.1 Sewerage and Drainage Act 2001

The Sewerage and Drainage Act 2001 (current as of 27 September 2020) is the primary statute that provides for and controls activities related to sewerage and land drainage systems. This section will only focus on the sections of the Act that are relevant to the research, such as drainage, stormwater and flood risk management. Within the Act, management of flood risks and the types of stormwater infrastructure are considered within the stormwater drainage system definition:

"storm water drainage system" means a system of drains for the conveyance or storage of storm water and includes —

(a) any weir, grating, float, boom, gauge, tidegate, sump, storage pond, pumping station, maintenance access, and debris interception and removal facility related to such system;

(b) any structure constructed to convey, store or measure storm water or for flood alleviation; and

(c) any bridge over or railing for any such drain or any appurtenance thereof

(Sewerage and Drainage Act 2001)

The Act primarily informs the responsibilities and powers of the Public Utilities Board (PUB) with regards to any public or private activities around storm water drainage systems and, such as construction; modifications; the protection of drains and drainage reserves; the capacity to instruct adequate drainage be provided in areas; the consideration and provision of clearance for works that may affect drainage system; vesting of drainage reserves.

Summary

The Sewerage and Drainage Act 2001 is an overarching statute that works to regulate sewage and drainage activities, including those that relate to flood risk management. The Act mainly contributes to flood risk management through defining the structural approaches used such as requiring flood defence infrastructure within the stormwater drainage systems, to help regulate stormwater flow and volume so as to mitigate flooding. The Act also describes the powers and roles of the PUB in relation to the building and management of the drainage systems. Overall, the Act functions to provide legislative guidance around the functions of the drainage network for the management of stormwater and thus flood mitigation.

7.2 Master Plan 2019

The Master Plan 2019, as described in the Singapore context, is the main statutory land use plan that directs and regulates development for the following 10 – 15 years and provides land use plans for Singapore's planning areas (URA, 2020b). The parts of the Master Plan 2019 that are of relevance to this research are its 'Themes', 'Regional Highlights' and 'Urban Transformations' (URA, 2020b). Out of the five major themes flood risk is considered in A Sustainable and Resilient City of the Future' and 'Liveable and Inclusive Communities'. In 'A Sustainable and Resilient City of the Future', the relevant sub-theme of climate change adaptation includes the mitigation of flood risks, which are largely addressed by PUB through the source-pathway-receptor approach; this will be further explained in the section 7.3. The relevant sub-themes within 'Liveable and Inclusive Communities' demonstrate the inclusion of BGI concepts (URA, 2020b):

- Urban greenery, roof gardens, bio-swales and rain gardens in upcoming housing precincts will manage stormwater while helping to reconnect people with nature;
- HDB will maximise the potential of ecosystem services in new public housing, wherein flood hazard mitigation and stormwater management services utilise BGI measures (Tan *et al*., 2018);
- BGI strategies will continue to be implemented in recreational areas, particularly through the Active, Beautiful, Clean (ABC) Waters Programme to deliver to overarching concept of a 'biophilic City in a Garden';
- Providing BGI features in developments to sustainably manage rainwater by reducing runoff flow while boosting the urban greenery.

Various areas of each region in Singapore are identified in the 'Regional Highlights' theme where strategies and their associated projects on developments and land use consider the integration of green and blue spaces for a multitude of uses such as stormwater management, recreational spaces, green linkages, amenity, greening developments and nature parks. Holland Plain is an example of a Central Region future project that includes stormwater management as an objective by using WSUD components. The 'Urban Transformations' projects are main growth areas that aim to stimulate economic development and reduce distance between residents and employment and amenity locations (URA, 2020b). These projects largely revolve around smarter ways of developing urban spaces; they do include the integration of green spaces and waterways but for the purpose of recreational amenity or nature-integrated urban living. Notably, the Kallang River transformation (addressed in section 7.4) includes enhancements through the ABC Waters Programme but will include various revitalisation projects in the neighbouring areas along the River to provide enhanced connectivity and mixed-uses (URA, 2020b).

Summary

The use of BGI strategies is noted to be a core concept interspersed and interwoven all throughout the Master Plan 2019, going beyond its initial conceptualisation and implementation through the ABC Waters Programme, where it was used as an alternative method to deal with flood risks while providing additional benefits, to now a widespread adoption in various sectors in a bid to sustainably address various urban issues, and to reconnect people with nature towards a more sustainable future. It is clear that a seamless integration of BGI into the urban environment is the vision that Singapore is working towards, also known as a 'City in a Garden'.

7.3 Managing Stormwater for Our Future and Code of Practice on Surface Water Drainage

The Managing Stormwater for our Future Publication (hereafter, MSOF Publication) shares the stormwater management approach, strategies and criteria undertaken by the Public Utilities Board (PUB), along with improvement plans for 12 of Singapore's waterways. Observations of growing severe rainfall and urban expansion has led to an increasing exposure to floods, which has led the PUB to reassess their stormwater management strategies to improve the management of floods in Singapore. Since the MSOF Publication (PUB, 2014), the PUB has adopted a system-wide integrated outlook for Singapore's drainage systems where canals and drains were improved upon and amendments were made to the Code of Practice on Surface Water Drainage (COP) (released under the Sewage and Drainage Act), enabling them to be more versatile when facing severe rainfall (PUB, 2014). The PUB has three overarching stormwater management strategies shown in Figure 7.1.

Figure 7.1 *Public Utilities Board's Stormwater Management Strategies.*

Getting it Right from the Start

- PUB collaborates with planning and development agencies to allocate land for drainage systems and initiate new drainage schemes before new towns or other development projects commence.
- Monitoring and targeting flood prone areas with flood alleviation projects.
- Enforce drainage requisites, building plans and development controls.

Setting out Clear Guidelines

- Flood protection requisites that are to be implemented are defined in PUB's Code of Practice on Surface Water Drainage for all new developments and redevelopments.
- These requisites include planning considerations of developments and design considerations of drainage systems.

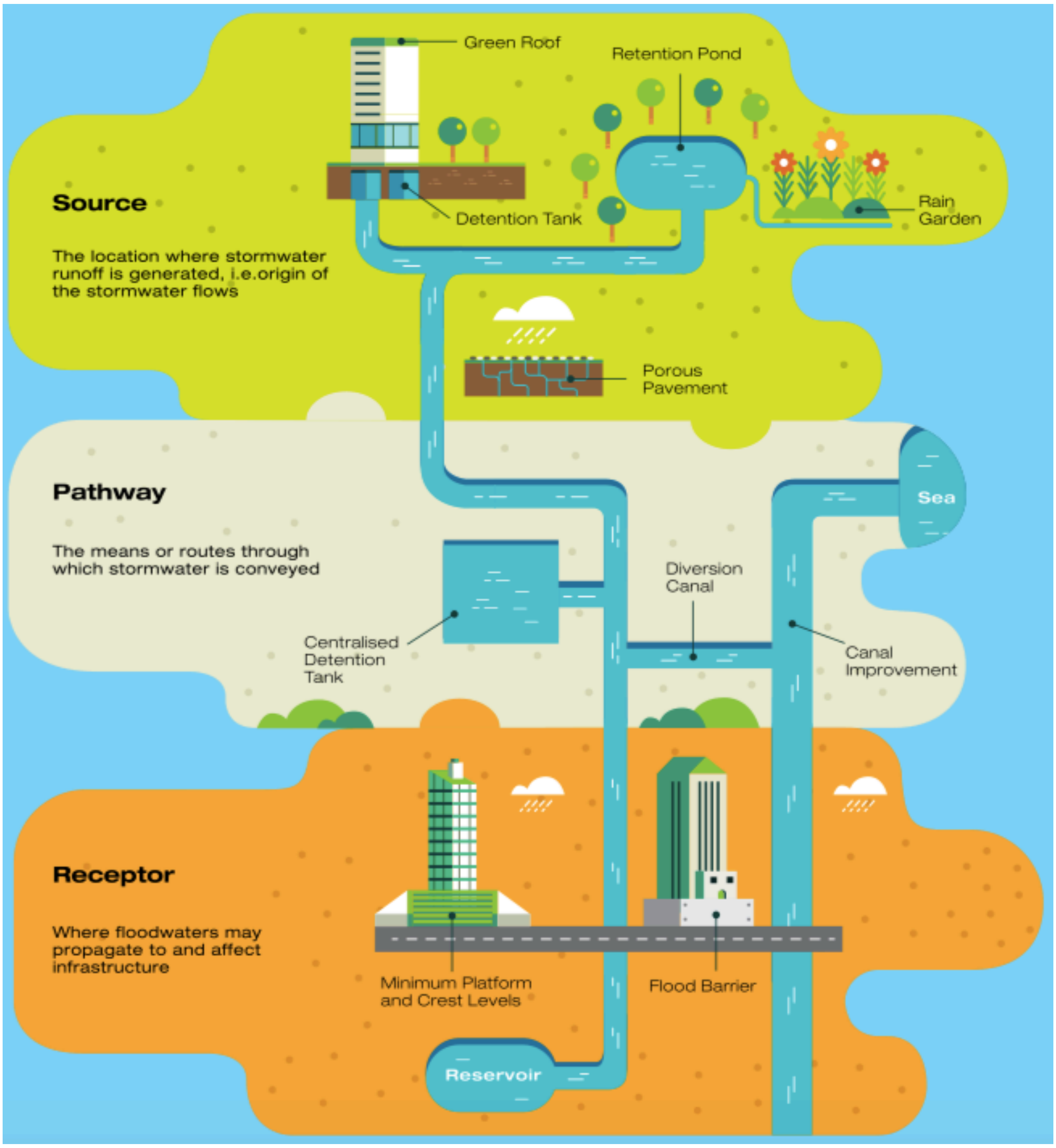
Continuous Enhancements

- Drainage systems are constantly upgraded by PUB to comply with more rigorous drainage design standards for flood protection and to improve the drainage systems' capacity, particularly in mature and developed areas that face increasing development and redevelopment.
- Examples: upgrading waterways, constructing diversion canals and centralised detention tanks, elevating roads and grounds.

Note. Public Utilities Board's system-wide approach of stormwater management strategies (content adapted from Public Utilities Board, 2014; Expert Panel on Drainage Design and Flood Protection Measures, 2012).

As part of the system-wide approach, PUB (2014) uses a 'source-pathway-receptor' approach across the drainage network which is a holistic way of dealing with flood risks by supporting effective drainage and complying with the flood protection standards. Targeted and fit-for-purpose stormwater management solutions are established at each part of the 'source-pathway-receptor' approach to deal with runoff as effectively as possible. At the source, BGI measures such as rain gardens and wetland ponds are incorporated in addition to grey infrastructure; the Publication details some examples: bioretention basins at Balam Estate, dry ponds at Greenwood Sanctuary, a green roof and garden built on the roof of Orchard Central Mall (PUB, 2014). Pathway solutions involve making modifications to increase canal capacity or providing diversion canals to central detention tanks in areas with space constraints, while solutions at the receptors use structural and non-structural measures to manage flood risks, such as flood barriers and flood alerts respectively (PUB, 2014). This approach is shown in Figure 7.2.

Figure 7.2 *Public Utilities Board's Multi-Pronged Drainage Solutions.*



Note. Public Utilities Board's 'source-pathway-receptor' approach towards stormwater management (image adapted from: Public Utilities Board, 2014, p. 9).

The minimum engineering criteria needed to plan, design, and build drainage systems are described by PUB's COP, which has been improved through the upgrading of flood protection standards and the capacities of drainage systems (PUB, 2014). As drainage upgrades are not only done for mature drains or areas that have experienced floods but are also pre-emptively conducted for new developments, it signals that the PUB has a short to long-term outlook in managing stormwater so as to mitigate future floods. The COP provides guidelines for the development of solutions for the 'source-pathway-receptor' approach, some examples are (PUB, 2014; 2018d):

- Source solutions – Through the COP Clause 7.1.5, developers are obligated to incorporate ABC Waters design features and/or on-site detention and retention measures (for example detention tanks, retention ponds, wetlands, bioretention swales, bioretention basins, porous pavements) on recently developed and redeveloped sites that are 0.2 hectares or larger, which will regulate and reduce peak runoff by 25-35%.
- Pathway solutions – The upgrade of drainage design standards in 2011 will allow an increase of 15-50% in the drainage system capacity of catchments.
- Receptor solutions –
    - Minimum platform and crest level requirements under COP Clause 2.1 and 2.2 were increased to supply increased flood protection (for example, using steps and ramps to meet the minimum platform levels).
    - Minimum platform and crest level requirements under COP Clause 2.1, 2.2, 2.4 for commercial and multi-unit residential buildings with basements, and buildings with underground linkages to Mass Rapid Transit stations were revised to upgrade flood protection (for example, using ramps to meet minimum crest levels for basement entrances).
    - Includes provisions for flood protection measures to provide developers with options to safeguard their developments while maintaining pedestrian connectivity (for example, installing manual or automatic flood barriers).

The MSOF Publication also briefly covers PUB's work through the ABC Waters programme to contribute to pathway solutions by integrating the systems into the wider environment so as to reduce peak runoff, improve water quality and connect people with water systems. Through the ABC Waters master plan (addressed in section 7.4), a watershed-focused planning approach was used, where Singapore's land mass was visualised as three primary catchments (east, central and west) based on their land use. Various upgrades and future improvements for 12 waterways located across Singapore are summarised in Table 7.1. An overview of the current (as of 2020) drainage upgrade projects are shown in Figure 7.3, and projects done in conjunction with the Estate upgrading programme are shown in Figure 7.4.

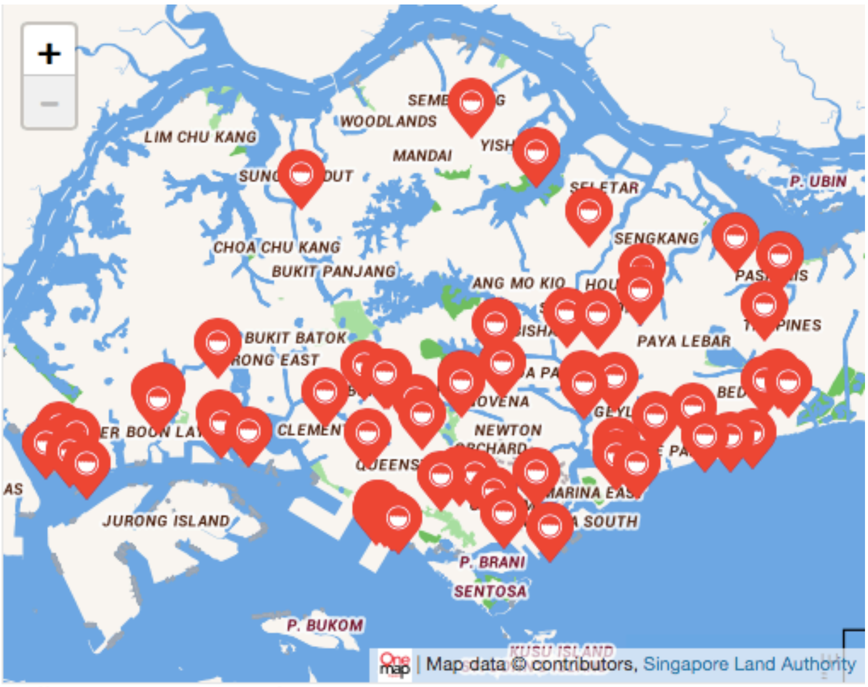
Table 7.1 Past to Future Upgrades for 12 Singapore Waterways.

Watersheds	Waterways	Upgrades
Western watershed	Bukit Timah Canal (midstream-downstream sections) to Bukit Timah First Diversion Canal to Sungei Ulu Pandan	• Work done in 2013 to expand and deepen a section of Bukit Timah Canal. • Plans to upgrade protection for catchment against heavy storms were done in 2015-2017 and 2019, with an ongoing project to be completed in 2023.
	Sungei Pandan Kechil	• Minor drainage upgrades to increase stormwater flow. • Flood protection improvements for the nearby Ayer Rajah Expressway were done in 2018 and 2019.
Central watershed	Bukit Timah Canal (midstream-downstream sections) to Rochor Canal	• Under ABC Waters Programme, Rochor Canal will be reworked into a river promenade. • Enhancements upstream completed by 2016. • Future plans to improve drainage capacity.
	Alexandra Canal	• Drainage enhancements completed in 2015 and 2017 to mitigate flooding in neighbouring areas and handle greater flows. • Ongoing project to be completed in 2021.
	Stamford Canal	• Provision of centralised detention tank and diversion canal in 2018 to divert runoff flow to Singapore river to alleviate flooding in the nearby Orchard Road area.
	Kallang River	• Upstream section of Kallang River was redeveloped in 2012 into a ‘naturalised river’ containing ABC Waters elements and was integrated into the Bishan-Ang Mo Kio Park.

		• Improvements done in 2019 and ongoing project to be completed in 2021. • Future plans to expand the downstream portions of Kallang River, including naturalising a section.
	Geylang River	• Improvements to upstream section of the Geylang River finished in 2013 and 2015. • Ongoing project to be completed in 2021. • Future intentions to administer source and/or receptor initiatives to address low-lying areas.
Eastern Watershed	Bedok Canal	• Future plans to deepened and widened downstream portion and implement ABC Waters elements for revitalisation, this will be done in phases from 2015-2020.
	Siglap Canal	• Canal to be broadened and deepened in phases. • First phase commenced in 2014-2016 along with an ABC Waters project. • Following phases to be implemented based on canal conditions and development rate.

Note. Summary of upgrades conducted and to be initiated by the Public Utilities Board for 12 waterways to improve management of stormwater and flood risk (content adapted from Public Utilities Board, 2014; 2020a).

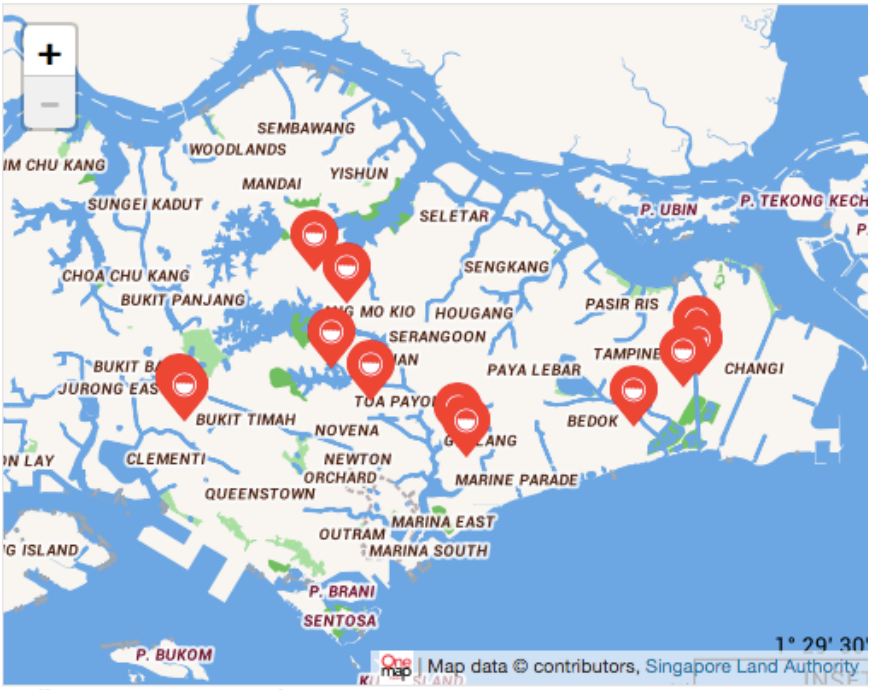
Figure 7.3 Current Drainage Projects in Singapore.



* All map points are indicative

Note. A map overview of the current drainage upgrade projects in Singapore (image source: Public Utilities Board, 2020b).

Figure 7.4 Current Drainage Upgrade Projects with Estate Upgrading Programme.



* All map points are indicative

Note. Current drainage upgrade projects in conjunction with Estate upgrading programme by Ministry of National Development (image source: Public Utilities Board, 2020b).

These upgrades are tailored to suit the conditions of the waterways and the urban areas, with many upgrades incorporating ABC Waters aspects to provide multiple benefits to the public. The PUB (2014) strives for ‘collaboration and capacity building’ where PUB engineers, modellers and planners collaborate with stakeholders, contractors and consultants to plan and design stormwater drainage systems. This is similar to Brisbane where, state level and local level documents in general, emphasise collaboration between councils, the private sector, public institutions and the community. However, through the documents related to Brisbane’s flood risks in Chapter 6, more uncertainty exists at the state level around the manifestation of these collaborations as some of them lack an implementation plan, compared to the local level documents which supply more concrete information around actions. Additionally, developers are encouraged to participate in stormwater-managing by using source and receptor solutions to increase the flood resilience of their buildings. The Handbook on Managing Urban Runoff was released by PUB (2014) and Institution of Engineers to provide information on successful stormwater drainage designs and flood protection strategies and COP criteria. The Technical Guide on On-site Stormwater Detention Tank Systems was also released by PUB (2014) to give technical guidance on how to plan, design and administer stormwater detention tank systems in developments.

Summary

The MSOF Publication outlines in detail the PUB’s integrated stormwater management approach that works with the COP and collaborates with other planning and development agencies to plan for the country’s drainage and flood risks alongside land development. Flood risks are addressed in a holistic manner through the PUB’s ‘source-pathway-receptor’ approach, which integrates with the pathway solution upgrades under the ABC Waters Programme. Additionally, the Publication address how other guidelines support the overarching stormwater management approach to mitigate floods. This demonstrates a proactive flood risk management mindset that aims to consistently work on improving current and future flooding and drainage issues; an understanding of the consequences of flooding to the public if flood management is not regularly maintained and improved upon; and strategic thinking to enhance the country’s drainage systems while dealing with land constraints.

7.4 Active, Beautiful, Clean Waters Programme: Water As An Environmental Asset

The Active, Beautiful, Clean (ABC) Waters Programme: Water As An Environmental Asset is a publication by the CLC (2017) that shares Singapore's efforts in reworking its drainage network through the ABC Waters Programme into multifunctional spaces for the public to appreciate and interact with. Through interviews and engagement with stakeholder organisations and practitioners, history and knowledge on planning and implementation processes have been compiled into this publication to provide guidance on water management for professionals and the wider community (CLC, 2017). The management strategy of the ABC Waters Programme actively encourages the use of natural systems and ABC Waters design elements to soak up and store stormwater so as to decrease peak runoff to the waterway system and mitigate flood risk when storms occur (CLC, 2017). The strategy also promotes the integration of systems into the landscape, where such spaces function as infrastructure and community facilities; the strategy is embodied in the ABC Waters Programme's name (CLC, 2017):

- **Active**: Creating new recreational and community spaces while bringing people closer to water.
- **Beautiful**: Transforming concrete waterways into vibrant and picturesque waterscapes that are well integrated with the urban environment.
- **Clean**: Improving water quality through holistic management of our water resources and public education by fostering better people-water relationships.

The Publication shares the ways in which the ABC Waters Programme manifests the following broad principles of the Singapore Liveability Framework's systems of urban planning, shown in Table 7.2 below.

Table 7.2 *Active, Beautiful, Clean Waters Programme Embodying the Singapore Liveability Framework.*

Systems of Urban Planning	Principles	Applications
Integrated Master Planning and Development	Fight Productively	• PUB collaborates with other agencies to create multi-functional spaces where water was integrated into the surrounding urban infrastructure. • 'Productive fights' amongst agencies gave rise to improved inter-agency coordination and the creation of future projects like the Bishan – Ang Mo Kio Park project.
	Execute Effectively	• ABC Waters Master Plan guided the administering of the ABC Waters Programme. • Programme was heavily supported by agencies and political leaders who grasped the programme's worth and resulted in consistent and effective execution.
	Innovate Systemically	• Pioneering engineering techniques in the Programme resulted in deeper integration of drainage infrastructure with urban landscape and provided diverse uses. • Pilot projects and demonstration sites were created to evaluate the effectiveness of stormwater flow and public uptake.
Dynamic Urban Governance	Involve Community as Stakeholders	• Involvement of local communities in protecting water resources. • ABC Waters Learning Trail and school adoption programme promoted school adoption of water sites, drawing communities to appreciate water.
	Work with Markets	• Private sector contributed to effective implementation of the Programme by employing their expertise in bioengineering treatments for waterways. • ABC Waters Certification and private sector partnerships promoted the adoption of the Programme

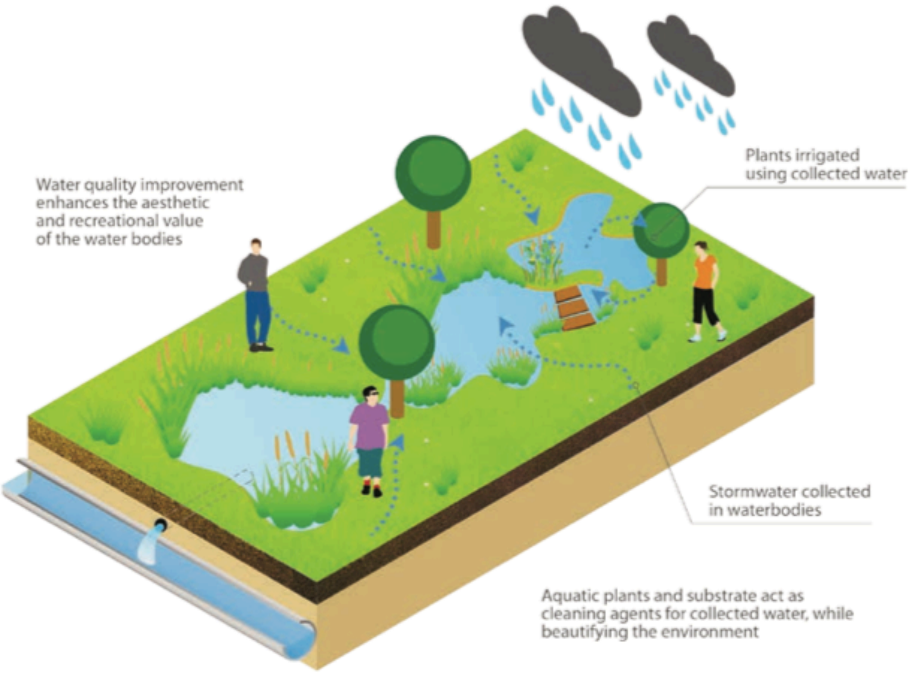
		by private developments who implemented ABC Waters design elements.

Note. Summary of how the Active, Beautiful, Clean Waters Programme exhibits the principles of the Singapore Liveability Framework (content adapted from Centre for Liveable Cities, 2017).

The ABC Waters Programme aims to reinvent Singapore's drainage and water storage grey infrastructure by integrating it with natural features to not only manage and reduce flood risk but also develop them into active and engaging spaces to contribute to the community's quality of life and recreational use, and overall sustainability. This programme also strives to integrate the community with the local water sources and develop public stewardship to water and the environment (CLC, 2017), undertaking a government-driven but community-focused approach. This is contrasted with Brisbane which has dedicated BGI projects that are both community-driven and community-focused, indicating that current wider applications of BGI in Brisbane typically function through a more localised grassroots approach, with government support.

Main motivations resulting in the ABC Waters Programme uptake can be seen through the use of design, regular improvements of the local waterways and waterbodies and provision of amenities to attract and welcome the community. This programme is aligned with the government's actions of the 1980s that saw the use of greenery to revitalise urban spaces, where it uses BGI measures (particularly WSUD, SUDS and LID methods) and international knowledge to develop a programme that was beyond anything similarly conducted overseas (CLC, 2017). Design features used in the ABC Waters Programme work to treat and reduce runoff flow rate, which will help to alleviate flood risk and decontaminate water before it flows into the waterway network (CLC, 2019a). The functionality of conventional stormwater infrastructure is increased through this programme by enabling them to store water to reduce pressure on the network and to be recreational spaces for the public (CLC, 2019a). These projects also support and increase local biodiversity, improve urban amenity and provide educational opportunities for the public to interact with green and blue spaces (CLC, 2019a). The ABC Waters Programme's concept is visualised in Figure 7.5.

***Figure** 7.5 The Active, Beautiful, Clean Waters Design Features.*



The ABC Water Design Features.

Implementing the ABC Waters design features within developments would improve the quality of stormwater surface runoff while beautifying urban environments.

Diagram Courtesy of PUB, Singapore's National Water Agency.

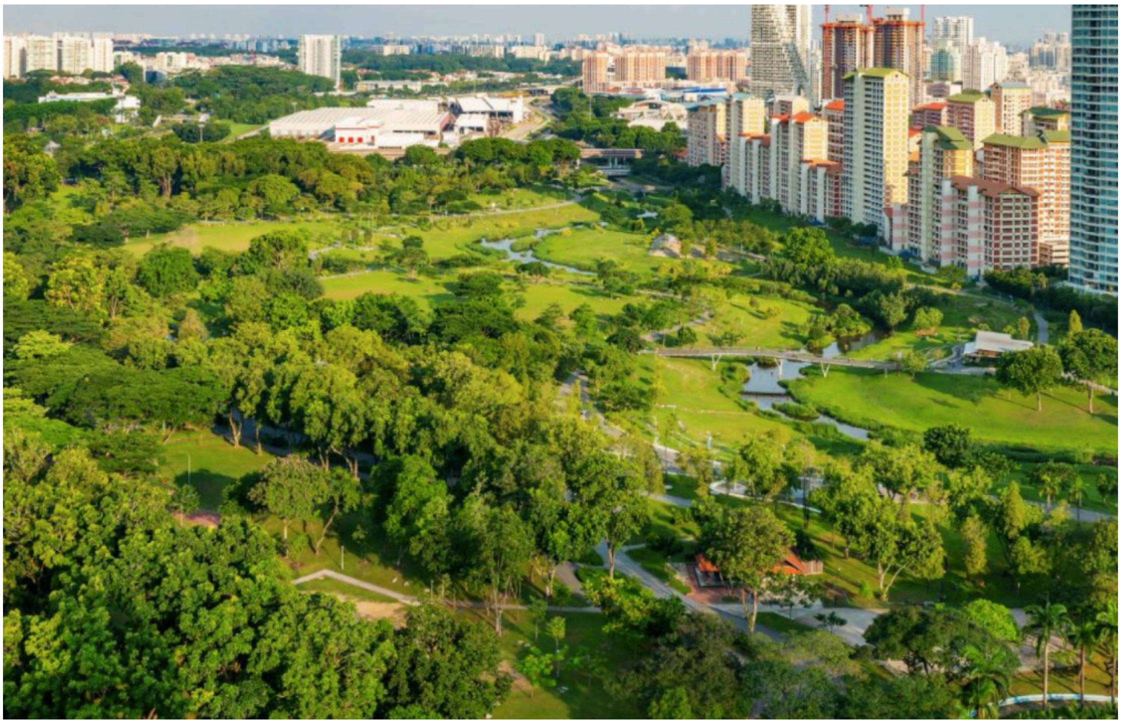
Note. Conceptualisation of the implementation of features of the Active, Beautiful, Clean Waters Programme (image source: Public Utilities Board as cited in Centre for Liveable Cities, 2017).

A cornerstone of the ABC Waters Programme's is the 3P (People, Private, Public) Network which was developed by the PUB to provide a holistic way of establishing connections and engagement with people, the public and private sectors to support PUB's projects and involve them in water management (CLC, 2017). Realising at the start that it lacked the expertise to plan the ABC Waters concepts, PUB actively engaged experienced consultants that had utilised ABC Waters design features and could offer international and inter-disciplinary knowledge (Tan *et al.* 2009). The 3P Network also helped PUB to understand the needs and desires of the public (Tan *et al.,* 2009). This led to the creation of a Master Plan to institutionalise the Programme so that it would be officially recognised and supported, and also describes the catchment planning approach used nation-wide (addressed in section 7.3), where each catchment had an approved consultant plan and tailor ABC Waters sites according to those features; thereafter the ideas were expanded upon by PUB and other government agencies

(CLC, 2017; Tan *et al.* 2009). Another key planning area of this Programme is the knowledge exchange that the PUB did with Melbourne Water on their established examples of WSUD (CLC, 2017). This not only helped to guide the applicability of designed concepts for Singapore and the ABC Waters Programme, it also helped to persuade and assure PUB's engineers of the concepts' practicability (CLC, 2017). Following this, the ABC Waters master plan determined 100 prospective sites that were estimated to be administered by 2030, where works would take 20-30 years (CLC, 2017; Khoo, 2016).

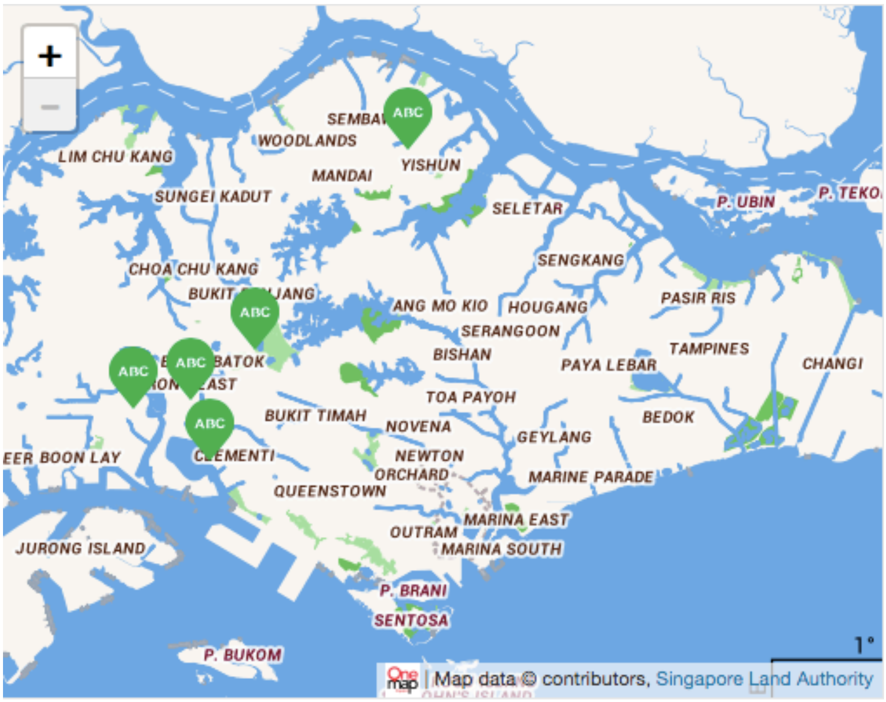
The success of the Programme also relied heavily on political and public awareness and support, this was garnered by the PUB through a comprehensive public relations campaign that included the ABC Waters Exhibition 2007, which shared plans for upcoming projects; a roadshow at community hubs; and demonstration projects were created in Kolam Ayer and Bedok Reservoir in 2008 and MacRitchie Reservoir in 2009 (CLC, 2017). By showcasing the envisioned projects and providing information, the PUB was able to get politicians and the public on board with the Programme, which ensured its longevity and anticipated that these projects would be well-used by the public in future (CLC, 2017). In June 2017, 36 projects had been concluded, some of which were Alexandra Canal, Rochor Canal, Lower Seletar Reservoir and the flagship project of Kallang River at Bishan-Ang Mo Kio Park (CLC, 2017; Khoo, 2016). Figure 7.6 shows the ABC Waters flagship project of the re-naturalised Kallang River and the redesigned and upgraded Bishan-Ang Mo Kio Park. Figure 7.7 shows a map overview of the ABC Waters projects that are currently ongoing as of 2020.

Figure 7.6 *Re-naturalised Kallang River and Bishan-Ang Mo Kio Park.*



Note. Active, Beautiful, Clean Waters flagship project of the re-naturalised Kallang River and the redesigned and upgraded Bishan-Ang Mo Kio Park launched in 2009 and completed in 2012 (Image source: Ramboll Studio Dreiseitl, n.d.)

Figure 7.7 *Current Active, Beautiful, Clean Waters Projects.*



* All map points are indicative

Note. A map overview of the current Active, Beautiful, Clean Waters projects in Singapore (Public Utilities Board, 2020b).

Active collaboration amongst agencies and practitioners of various skill sets was also core to streamlining various perspectives and agendas, and to harness the expertise that was needed to bring projects to life; these included government agencies such as NParks, URA, HDB and JTC, in addition to agencies from the private sector. The PUB's long-term outlook to strengthen the ABC Waters Programme also involves establishing future capacities through sub-schemes such as the ABC Waters Design Guidelines, Building and Construction Authority's Green Mark Scheme, the ABC Waters Certification Scheme and ABC Waters Professional Programme (CLC, 2017; Tan *et al.* 2009):

- ABC Waters Design Guidelines was released in 2009, 2011 and 2014 to provide guidelines on water-sensitive features and design.
- The Green Mark Scheme was revised to include the consideration of ABC Waters design features administered in buildings in its green building rating system.
- The ABC Waters Certification was created in 2010 to assess developments based on their inclusion of ABC Waters design features and awards their efforts. 62 projects with ABC Waters design features have been certified as of April 2017.
- The ABC Waters Professional Programme was created in 2011 to upskill relevant practitioners in ABC Waters design.

These schemes help to incentivise developers into being involved through the design of developments and educate them in the importance of these features to alleviating flooding and improving overall sustainability and liveability along with building a pool of local expertise by training practitioners in ABC Waters design. Moreover, promoting public ownership of the Programme's project sites have led to the adopting of ABC Waters sites by 321 organisations as of 2017, showing the vested interests that the public increasingly now have in local blue and green spaces (CLC, 2017). The ABC Waters Programme's activities will continue to develop as practitioners assess and innovate over areas of improvement and capitalise on BGI strategies to help blue spaces and green spaces function as part of the urban fabric to not only manage flood risks for the future but also offer many sustainable benefits for urban liveability.

Summary

The Active, Beautiful, Clean Waters Programme: Water As An Environmental Asset publication describes in depth the government's efforts in using the ABC Waters Programme to transform its drainage network beyond its drainage functions to provide other uses to the public. The Programme focuses on using international expertise and BGI principles that were adapted and innovated to suit the local context, along with active agency and private sector collaborations and community engagement. Design, upgrades, amenity provisions and public relations are also seen to be important to the development and uptake of the Programme, with other supporting sub-initiatives that encourage the involvement of developers and communities. The government can be seen to be proactive and dedicated in the planning and integration of BGI into Singapore's landscape through the steady operation of this programme over the past 14 years, with multiple completed and ongoing projects that demonstrate this.

7.5 Analysis of Planning and Policy Documents: Comparing Brisbane and Singapore

As previously explained in the literature review chapter, flood risk management frameworks, their strategies and implementation actions, are dependent on the areas of focus deemed important by the countries and agencies that develop and implement them, but all of them work towards managing and alleviating flood risks. To understand how planning and policy documents and approaches design flood risk management frameworks and incorporate and implement BGI, scoring schemes (shown in Tables 7.3 and 7.4) were created. As described in the method's section 3.3.4, the schemes' criteria were based off the five general flood risk management strategies and six core areas of BGI that are key to the infrastructure's successful implementation, as derived from the literature review. The documents and approaches of both case studies are then scored within the schemes and analysed to glean insights around the focus placed on flood risk management and BGI. In looking at the documents and approaches, It should be noted that as per the literature review, any combination of flood risk management strategies may be used to form a flood risk management framework to suit the local context, whereas successful implementation of BGI requires fulfilment of all criteria; this will be further explained in this section.

For flood risk management, the scoring scheme will demonstrate the strategies chosen, whether singular or in a combination, and the level of consideration of the chosen strategies. Where a strategy was not considered within a document, a grey box was displayed. A score of 1 was allocated where a document expresses some consideration with little detail given about a strategy. General consideration and some details of a strategy demonstrated in a document was given a score of 2. If a document describes precise recognition and implementation of a strategy, a score of 3 was given.

Table 7.3 *Scoring Scheme to Assess Flood Risk Management Strategies.*

Documents	Flood Risk Management Strategies				
	Flood Risk Prevention	Flood Defence	Flood Risk Mitigation	Flood Preparation	Flood Recovery
National Strategy for Disaster Resilience (2011	2			2	2
National Disaster Risk Reduction Framework (2018)	1			2	1
Disaster Management Act 2003				1	3
State Planning Policy (2017)	3				
ShapingSEQ – South East Queensland Regional Plan 2017	3				2
Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience (2017)	1			2	1
Brisbane River Strategic Floodplain Management Plan (2019)	3	3	2	3	2
Brisbane City Council Local Disaster Management Plan	1	1	1	3	2
Brisbane City Plan 2014	3	3	3	3	
Brisbane's FloodSmart Future Strategy 2012-2031	2	2		2	
Oxley Creek Master Plan	3	3	2	3	2

Sewerage and Drainage Act 2001		3			
Master Plan 2019	3	2		2	
Managing Stormwater for Our Future (2014) and Code of Practice on Surface Water Drainage	3	3			
Active, Beautiful, Clean Waters Programme	3	3		2	

Note. Checklist of flood risk management strategies considered in each planning and policy document.

There is a great amount of variation within the documents shown in Table 7.3 in terms of the flood risk management strategies chosen for their flood risk management framework, where some employ one strategy while others use a combination of strategies. It is observed that the number of strategies used do not necessarily represent a reduced capacity in flood risk management, rather that these documents were issued with the purpose of them being complementary to each other at various levels, where some intended to cater to a specific purpose or area of focus, while others work through multidisciplinary and integrated approaches. Many of the higher-level documents for Brisbane tended to utilise a smaller number of strategies, showing a preference for flood risk prevention, flood preparation or flood recovery strategies. One state-level and all of the local level documents tended to employ a combination of more than three of the flood risk strategies, suggesting a more multi-faceted approach undertaken to deal with the varieties of flood types experienced locally. In contrast, the chosen documents for Singapore has a primary preference for flood risk prevention, flood defence and flood preparation strategies, likely due to the reduction in major floods over the years as a result of the flood risk management approach developed (as shown in Chapter 5).

To assess how the planning and policy documents and initiatives consider and incorporate BGI measures in their flood risk management framework and strategies, the evaluation criteria and a scoring system were obtained from the main themes that have arisen from the literature review. As outlined in the literature review, there are several core areas that are key to the successful implementation of BGI, these formed the six criteria of effective implementation of BGI:

A. Planning for a range of BGI measures;
B. Optimisation of BGI at various scales to support structural and non-structural approaches in flood risk management strategies;
C. Harnessing BGI's adaptability for a multiplicity of value-added functions;
D. Public participation;
E. Stakeholder engagement and collaboration;
F. Practicable and context specific application

To evaluate whether a document has considered these five criteria (labelled A – F), a score of 0 – 3 was given. Where a criterion is not mentioned within a document, a score of 0 was given. A score of 1 was allocated where a document expresses little to some consideration with minimal detail about a criterion. A general consideration and some detail of a criterion demonstrated in a document was given a score of 2. If a document describes precise recognition and implementation of a criterion, a score of 3 was given. The total score will be tallied and weighted against a total of 18, to demonstrate the level of consideration given to BGI within a document. Scores less than 6 will be considered to have a low level of consideration, scores of 6 – 12 will represent a medium level of consideration and scores over 12 will be considered to have a high level of BGI consideration. The scoring scheme is demonstrated in Table 7.4.

Table 7.4 *Scoring Scheme to Assess the Level of Incorporation of Blue-Green Infrastructure.*

Planning and Policy Document	Criteria						Total score
	A	B	C	D	E	F	
National Strategy for Disaster Resilience (2011)	0	0	0	0	0	0	0
National Disaster Risk Reduction Framework (2018)	1	0	0	0	0	0	1
Disaster Management Act 2003	0	0	0	0	0	0	0
State Planning Policy (2017)	1	0	1	0	0	0	2
ShapingSEQ – South East Queensland Regional Plan 2017	2	2	1	0	2	2	9

Strategic Policy Framework for Riverine Flood Risk Management and Community Resilience (2017)	0	0	0	0	0	0	0
Brisbane River Strategic Floodplain Management Plan (2019)	1	2	0	0	0	2	5
Brisbane City Council Local Disaster Management Plan	0	0	0	0	0	0	0
Brisbane City Plan 2014	3	3	0	0	0	3	9
Brisbane's FloodSmart Future Strategy 2012-2031	1	0	1	1	1	1	5
Oxley Creek Master Plan	3	3	3	3	3	3	18
Sewerage and Drainage Act 2001	0	0	0	0	0	0	0
Master Plan 2019	3	3	3	2	2	3	16
Managing Stormwater for Our Future and Code of Practice on Surface Water Drainage (2014)	3	3	3	0	3	3	15
Active, Beautiful, Clean Waters Programme	3	3	3	3	3	3	18

Note. Scoring scheme demonstrating consideration of effective implementation of BGI in planning and policy documents.

Through Table 7.4, it is noted that several documents do not consider or have minimal consideration of BGI; a reason for this would due to the documents' specific purposes, for example, legislation and statutory documents that provide guidance for particular areas of focus (such as drainage specifications), or overarching strategic documents that provide the strategic direction for users to subsequently develop concrete plans. Documents that do meet the BGI criteria to an extent or only include particular BGI criteria are typically those that are designed to have a broad focus such as regional development or floodplain management, rather than going into detail around the applications of BGI to contribute towards flood risk management. Documents that have a high level of BGI consideration are observed to be largely designed with the purpose of integrating and implementing BGI, these are more so at the local level for Brisbane and at the national level for Singapore. The high level of BGI applications in these documents indicate more focused efforts at the site-specific and local scale for Brisbane, where there is more room for implementation of measures in relation to flood risk management. In contrast, BGI applications in Singapore function across a national scale due to its centralised approach that integrates planning for BGI within its flood risk management system and has a whole range of implemented site-specific projects that demonstrate this ongoing consideration within its planning processes.

7.6 Concluding Discussion

The planning, policy and legislative frameworks pertaining to flood risk management in the Australia and Singaporean context have been discussed within this chapter. Few strategic directional frameworks exist at the Australian national level as it is a federal system, which means that the planning responsibilities largely lie at the state, territory and local levels. On the other hand, the Queensland Government has developed many strategic documents to address natural hazards and resilience, with flood risk management bundled under natural hazards. There are also some strategic directions and programmes specifically targeting the Brisbane River. However, the myriad of planning and policy documents issued at state level largely overlap in their approaches, strategies and policies; this, paired with a whole range of authorities and institutions responsible for different sections of flood risk management, may result in some confusion to decision-makers. Apart from the Disaster Management Act 2003 and the SPP which prescribes statutory actions, many of the other strategic documents only provide guidance on developing implementation plans and actions towards flood risk management.

In assessing the benefits and limitations of the approach to planning for flood risk management in the Brisbane River, it is arguable that there is a need to streamline the management strategies available to provide clarity for all entities that are seeking guidance on state-supported approaches. Additionally, in many Australian policy and planning documents, flood risk management is designed to be regulated as an element of a wider integrated approach, often times approaches that address flood risk management also address other water management or environmental issues as well. At the local level of Brisbane, approaches tend to provide more technical and preparative guidance for users, utilising a wider range of flood risk management strategies. Singapore has experienced similar challenges of streamlining flood risk management approaches in the past. However, motivations at a national level have led the government to overhaul conventional measures and adopt alternative flood risk management strategies early on with the support of stakeholders and the public, allowing a centralised governance approach to flood risk management. This can be seen through the chosen documents and their respective strategies for Singapore, where each have a specific focus yet are complimentary to each other to feed into the overarching vision of managing flood risks in an integrated and holistic manner. The findings from the planning and policy documents provide an overview of how the planning processes work in developing the flood risk management approaches used by each case study.

Through the scoring system tables, it is observed that most of the chosen documents at Australia's national and state level vary in the number of flood risk management strategies selected and do not give much consideration to BGI measures, with only one state level document having a moderate consideration BGI in its strategies. This indicates a broader focus on disaster management and regional development as a whole and a lack of BGI exploration at higher levels of flood risk management. As flood risk management is practiced at the state and local level, it could benefit from a larger focus at the state level, with a greater scale of BGI implementation to support current structural and non-structural approaches. There is a heavier inclusion of flood risk management strategies at the local level of Brisbane, which reflects the larger responsibilities held by the BCC to manage floods. A medium to higher level of BGI recognition and implementation is seen at the local level, indicating BGI measures may be easier to plan for and administer at a local to city scale to provide multiple benefits. These findings demonstrate the extent of BGI currently planned for while providing an idea of the capacity for it to be more widely implemented in future.

Whilst Brisbane varies in its combinations of flood risk management strategies, Singapore on the other hand, focuses more on flood risk prevention, flood defence and flood preparation strategies, indicating a tendency to work towards avoiding and alleviating floods while working to increase flood preparedness in its citizens. Singapore's documents demonstrate a larger scale of BGI applications, where BGI has been planned and integrated into nation-wide approaches, with emphasis on community and stakeholder participation, to allow future provision of BGI projects for a variety of functions. Rather than competing with other land uses, Singapore's approach to BGI integration is formulated to be as complementary as possible to current and future urban frameworks.

The following Chapter 8 will go through the findings from the key informant interviews and demonstrate the key insights offered around the effectiveness of the Brisbane City Council's flood risk management strategies, the issues impacting flood risk management (including BGI), the general areas of improvement for Brisbane and areas of learning for Brisbane through a comparison with Singapore's approaches.

8 Results – Key Informant Interviews

This chapter will follow on from the planning and policy analysis of Brisbane and Singapore and explore the perceptions and experiences around flood risk management and BGI within Brisbane and Singapore. Through key informant interviews, this chapter will aim to expand upon the flood risk management and Blue-Green Infrastructure (BGI) measures undertaken, their issues and potential areas of improvement. These findings will be presented in the following sections: views of flood risk management in Brisbane, issues impacting flood risk management in Brisbane, learnings for flood risk management in Brisbane.

8.1 Views on the Brisbane City Council's Flood Risk Management Strategies

Interview participants felt that the Brisbane floods of 1974 and 2011 were devastating events that caused a lot of widespread sociological, ecological, economical and physical damage to the inhabitants of Brisbane. A number of the participants who had experienced the 2011 Brisbane floods or had family and friends who had experienced the floods, particularly understood the severity of such an event and the importance of robust flood risk management. While the Brisbane City Council's (BCC) efforts in flood risk management were recognised by the informants to have improved since the 2011 floods, they had varying views of the performance of various flood risk management strategies; this will be explored below.

8.1.1 Flood Resilience Homes Programme and Voluntary Homes Purchase Scheme

There has been a gradual shift in development form, towards an embrace of the approach that Brisbane should be 'building up, rather than building out'. Informant B1 (BCC Councillor), shared that although the BCC does not prevent the construction of developments in flood zone, it now directs developments to relocate essential building utilities to a higher location to reduce damage and costs in the event of future floods. This was acknowledged by informants A1 (Climate Adaptation Science Academic) and A8 (Geomorphologist and Academic); they recalled the rebuilding of houses similar to the classic Queenslander two-storey houses that were elevated to allow water to flow through during floods. The Flood Resilient Homes Programme (delivered in partnership with BCC's sustainability agency CitySmart) which had stakeholder buy-in, is a strategy that improves the flood-resilience of residents' houses through works and financial assistance (B2, BCC Flood Policy and Planning Engineer). A5 (Historian and Academic) acknowledged Council's effort in engaging consultants and experts to retrofit, redesign and elevate houses through their Programme in several pilot areas, but noted that there may be concerns about the cost if this programme is applied to all flood-prone areas.

The Voluntary Homes Purchase Scheme, shared by informant B1, was an initiative where flood-prone properties can be purchased by the BCC at market value to help residents to relocate to safer locations, allowing the BCC to redevelop the land for more flood-adaptable uses. This scheme was seen by the informant as innovative and has helped to reduce flood risks in specific at-risk locations:

> *"So, we bought back I think about 21 properties in Rocklea and Archerfield. And that's basically bought them back and we've made that land parkland. So that's taken a lot of people that's taken a lot of people out on the flood zone." (B1)*

B1 did observe however, that this scheme seems to have stalled in some manner due to the absence of properties being purchased. The scheme was seen by A1 to have had a low uptake due to the low financial viability for residents; houses in flood-prone areas like Rocklea were not highly valued and therefore, market value payments offered by the BCC were insufficient to support residents in purchasing new houses elsewhere.

8.1.2 Flood Maps and Overlay Code

B2 (Flood Policy and Planning Engineer) stated that "*5000 people every day come online to Brisbane's flood information*"; this information is available on the BCC's website for planners, developers, insurance companies and property buyers to assist them in making optimal decisions around their investments, developments and properties. B2 mentioned that the BCC has a "*certain measure of success*" on the way people use these tools, however it is not fully clear what this benchmark(s) is for all tools.

B2 noted that around 1600-2000 people interact with BCC's flood maps. BCC informants (B1 and B2) explained that these maps provide people with information around flood risks and likelihoods. A way of determining the effectiveness of such strategies is asserted by B2 from the large number of users interacting with these tools. Conversely, several informants were unsure of or disagreed with the effectiveness of BCC's flood maps. Informants' views (Table 8.1) indicated that the BCC's flood maps were still lacking in accuracy and needed better consideration of climate change and land use factors, suggesting the need for flood maps to include long-term tracking indicators and an overarching layer that demonstrates on a wider scale the effects of climate change on existing flood risks, which could assist the wider public in understanding the potential wide-ranging impacts of floods.

Table 8.1 *Comments on Effectiveness of Brisbane City Council's Flood Maps*

"And whether you're in a flood zone, of course one of the kind of issues is that the land use has changed so much. The areas that flooded in 1974 were different to the areas that had flooded in 2011. So, how accurate are those flood maps, and then the next time a big flood comes through, will it be the same areas that will flood?" (A3, Environmental Psychology Academic)
"But it's still got flood maps that are based on key assumptions about how the dams will be operated. And it's not hugely clear from my reading at least, what those assumptions are, and it certainly wasn't clear what those assumptions are preceding the 2011 floods other than the fact that they assumed the dams would provide more flood risk mitigation potential than they actually did." (A4, Environmental Politics and Policy Academic)
"If we're looking at flood risk, then you have to ... look at climate change perturbations on that flood risk. And so, in Australia, engineers used to - it's called ARR ... the Australian Rainfall and Runoff methodology. Now ... it was only a year or two ago, that they included climate change perturbations into that. And so, doing that sort of regionwide flood mapping – but the mappings not easily available, you can search for your own house, individual properties, but you can't look at their collective overview." (C2, Climate Change Adaptation Specialist)

Note. Informants' comments on the effectiveness of Brisbane City Council's flood maps.

Like the maps, the Brisbane City Plan 2014's Flood Overlay Code was explained by B2 to supply the public with the information they require around development on flood-prone land. Informant A5 noted that the Flood Overlay Code was updated according to the recommendations of the Queensland Floods Commission of Inquiry (2012), and now appears to have more transparency around the mapping process and flood levels. The breadth of information and mapping now available for the public to assess flood-prone areas was acknowledged by informants A1, A5 and C3 (Water Management and Engagement Specialist). However, they highlighted the proverb of "*[let the] buyer beware*", wherein the public availability of information may allow for the shifting of responsibility from the BCC to the public to make the best decision to develop or settle on flood-prone areas. They also noted that people may not use the maps before purchasing a property, which A5 terms as a "*conscious decision*"; this would increase the public's exposure to floods and also results in blame-shifting should a flood occur in those areas. This view is shared below.

> *"Well, they're weighing it up. How much do I want to live in Graceville which I know floods, but I get this fantastic house it's got four bedrooms and a tennis court, it's what I've always wanted. Yeah, it's got a bit of a flood risk, but I'll take my chances. And people make decisions when they buy houses." (A5)*

Moreover, Informant C2 (Climate Change Adaptation Specialist) recognised the improving flood risk awareness from the Flood Awareness Map, but emphasised the need to display more specific flood risk indicators:

> *"I think you need to be measuring the numbers, you need to actually be tracking to say, 'Okay, Brisbane City is exposed to X number of things at the moment, and in five years' time or two years' time or one years' time it increases.' Then we've got it, we know that our policy is failing, and our planning is failing to either predict the changing fluid dynamics, or it's failing because we're still approving development in flood [prone zones]." (C2)*

The informants also highlight the importance for the BCC to consider other ways to supply people, who do not utilise the Flood Awareness Map or the Flood Overlay Code, with the information they need when developing or settling down. A good level of public interaction with the mapping and Flood Overlay code has been reported by BCC informants, however academic and consultant informants highlight the need to improve the Flood Awareness Map's accuracy through consideration of the unpredictability of flooding, particularly alongside climate change factors. Providing other ways to support those who do not use online resources in their decision-making, would not only help to reduce the shifting of responsibility when a flood occurs, but also allows all involved to take ownership of their decisions and nurture a supportive living environment. More transparency in these resources, could be achieved through the inclusion of risk indicators that tracks flood risk over the long-term as suggested by a key informant.

8.1.3 Infrastructure

The provision of infrastructure is a significant mechanism employed within the BCC's flood risk management framework that seeks to mitigate flood risks. Council and academic informants' views differed on the infrastructure used by the BCC. Informants B1 and B2 referred to backflow prevention devices as a key infrastructure measure, which is described within the BCC's *Local Disaster Management Plan* and considered these devices to have been an effective measure in reducing flood risks. However, many academic and consultant informants called attention to the Wivenhoe and Somerset Dams in reference to the 2011 floods, particularly the dual functions of water storage supply and flood risk management that the dams presented. Several informants (A2, A4, A6, A8 and C2) either questioned the effectiveness of dual-purpose dams or were less supportive of such dams due to the operational conflict that is likely to happen when the need for flood mitigation arises, as seen in the events of the 2011 floods when decision-makers had to decide between prioritising water storage or flood mitigation. Informant A4 called out the "*ambiguities that were inherent in the dam protocols for the purposes of managing the 2010 and 2011 floods*", and indicated that the dam operators and government decision-makers needed to be explicit in their priorities for future management. It is important to be aware that even with well-planned operational manuals offering guidance during evolving flood situations, human errors can still occur in decision-making, with dam operators being under pressure to make the best judgement to alleviate floods (C2 and A5). Key comments addressing the functionality of dual-purpose dams are shown in Table 8.2.

Table 8.2 *Comments on Performance of Dual-Purpose Dams*

"And that sort of raises then the thorny issue of this zero-sum game that arises between flooding and drought management and you either keep water behind the dam or you let it go; if you do one, you compromise the ability of the facility to do the other. And I mean in practice, there are compartments within the volumetric capacity of the reservoir and that are strictly speaking assigned to one versus the other so, and 40% is for flood capacity and the other is for potable water supply capacity and then the sort of the excesses for safety, a safety margin but as we saw in both in the run up to the La Nina floods of 2010-2011, those considerations sort of gets blurred a little bit, the strict protocols." (A4)
"So, if you build a reservoir that you'll try to use for flood mitigation, irrigation and hydropower generation, you've got major conflicts because the reservoir's got to be full for hydropower and

draining down from a high value for irrigation but empty for flood mitigation. So, unless you've got a highly seasonal climate, it really can't work." (C2)

Note. A4's and C2's comments of the performance of dual-purpose dams for flood risk management.

Informant A4 added that people may assume that these dams provide a sense of safety from floods, in addition to being unaware of the invasiveness of dams on the "*broader social-ecological system*". A5 cautioned against full reliance on the dam, as seen in 2011, as it was likely not "*structurally possible*" to increase dam heights further due to physical limitations. These views indicate that there is still a gap in public knowledge around the limitations of the dams and the political motivations that surround their operations, which the BCC has appeared to not have adequately addressed. That, according to A5, added to a growing public realisation of other environmental problems and the damage done to natural hydrological patterns and waterways of the Brisbane River system leads to the need to consider alternative methods of managing flood risks.

8.1.4 Q100 Metric

The Q100, a metric used to inform BCC's initial flood risk management procedure, became controversial due to the way it was decided and utilised in the events leading up to the 2011 floods, as recounted by informant A4. The Q100 metric, signifies a 1% AEP which demonstrates a 1% chance of a specific magnitude flood occurring during any stated year, and this will recur on average every 100 years (QFCI, 2012). The metric is used to guide development locations, development types based on location, building heights of developments and other development guidelines as stated by A4 and B1. Informant B1 and C1 both asserted that through the Q100, BCC has offered more flexibility in building heights and construction regulations to increase flood resilience and keep housing affordable, although C1 observed that this was a discreet process.

Informant A4 noted that after the 2011 floods, BCC's planning guidelines no longer explicitly relied on Q100 and deduced that the BCC's flood maps were "*based on key assumptions about how the dams will be operated*". The informant found a lack of clarity in the specificities of these assumptions in addition to the pre-floods assumptions where it was assumed that the dams could supply a greater level of flood risk mitigation than in reality. Several informants (A1, A4, A5 and A8) suggested that the Q100 metric was more a political tool than a scientifically robust one and highlighted that the metric has been widely misinterpreted to mean a large flood occurring once every 100 years. Table 8.3 shows explanations of the Q100 definition (green boxes) against a misinterpreted view (orange box).

Table 8.3 *Comments on Brisbane City Council's Q100 Metric*

"Alternatively, you can think about these things as an annual exceedance probability that is, a one in 100-year event or one in 1000 year. so Q100 basically denotes an annual exceedance probability, but it's conflated with annual recurrence interval, which is not quite technically correct, but that's the way it was done for many years and one of the problems with that is that people misinterpret the metric." (A4)
"And the political decision that was taken was, one in 100 years is a pretty infrequent event. Now people misunderstand what that means. People assume that, okay, if we have a flood in 2011, we're not going to have another one till 2111, that's not what it means. It means that every year is at least a 1% chance on average that you're going to have a flood, a major flood. But you know, we saw it in 1974, we saw in in 2011, that that was twice within less than a half century. So, you know that, that frequency can vary quite a lot." (A1, Climate Change Adaptation Science Academic)
"The data has always got uncertainties ... and gauging a big flood has got at least a 30% error. Yeah. So, [these flood forecasting metrics have] all got problems, that these very short records are really quite dangerous in some ways." (A8, Geomorphologist and Academic)
"So that Q1 means it floods every year. Q2 means it floods every second year. And Q100 means it floods once in 100 years, so that's sort of how we gauge flooding in Brisbane." (B1, Councillor)

Table 8.3. Informant A4 and A5's explanations versus B1's comments of the Brisbane City Council's (BCC) Q100 metric.

Similar to the maps, A5 suggested that users do not entirely rely on the Q100 metric, as residents or developers may still infill on lower levels with a granny flat or a room. A4 explained that using the Q100 to inform BCC's planning framework creates limits on development locations, which could cause issues should the BCC need to revise this metric in future:

> *"Now if you backtrack, if you make that level higher than it was originally set, then what you're saying to property owners that have already built within the Q100 level with appropriate provisions – what you've said is that their flood risk is significantly higher than what you would usually have followed. Now that says bad things, for the electability of Brisbane City Council in terms of the next electoral cycle, because you've cost property owners the value on their properties." (A4)*

There appears to be a decreasing overreliance on the Q100 metric by the BCC after the events of 2011 although it is still used in guiding development regulations, however many informants highlighted the gross misinterpretation of the meaning of the Q100 metric to indicate the occurrence of large floods once every 100 years. There is a strong need to improve the understanding of this metric and the level of reliance that can be afforded when using it.

8.1.5 Flood Information, Modelling, Alerts and Insurance

B2 shared that Council's range of flood preparation information and advice provided to the public for oncoming storm seasons involved checking gutters, cleaning up backyards, looking out for the elderly and children, identifying their evacuation routes, insurance, and business continuity plans for businesses. This information was perceived to be comprehensive by B2 and C3 (Water Management and Engagement Specialist). B2 also considered BCC's flood risk management strategies effective, emphasising that the Council consistently works on improving its strategies and flood risk information to meet the public's needs. Flood modelling, sandbags, storm warnings, emergency assistance and insurance are other flood risk management strategies stated by B2, that are also described in the BCC's Local Disaster Management Plan (2018). Informants A1 and A3 also noted BCC's and the Bureau of Meteorology's efforts in sending storm and flood warnings to the public and businesses.

Although BCC's increasing efforts in modelling are recognised, informant A5 recalled conversations with insurers who cautioned that some places in Brisbane (and other parts of

Queensland) will be uninsurable in future, because high flood risks will be identified through risk assessments that will escalate insurance costs. C1 (Landscape Architect) suggested that results from flood modelling should be presented as a range, to account for the complexity of modelling and the variable nature of flooding:

> *"The model of complex modelling that comes into play to arrive at a line in the sand you know, it's a bit like that town planning comment I made before you know, they're dangerous things. [We] really should be talking about sliding gradients rather than specific levels." (C1)*

Flood risks are also managed to an extent by local government's building codes and emergency management regulations, along with research conducted through the State's Brisbane River Catchment Flood Study (C2). The findings show that there is a range of flood risk management strategies employed by the BCC, but there is also a need to be aware of and address the impacts of increasing flood risks on the future effectiveness of these strategies, particularly in modelling and insurance.

8.1.6 Blue-Green Infrastructure Efforts

There have been efforts to implement and integrate BGI within Brisbane's urban environment, ranging from small to medium scale projects. B2 shared that the BCC has been considering a combination of BGI and grey infrastructure approaches to manage creek and overland flow flooding. They listed "rainwater tanks, stormwater harvesting solutions, retention, detention and wetlands" as some BGI methods that are also "*hard-coded*" in the Brisbane City Plan 2014. Informant B1 acknowledged that although Brisbane's drainage networks were built to manage runoff and natural flows, the flow rate has drastically increased instead and contributed to flooding in the suburbs of Rocklea and Archerfield. They indicated that meetings with residents have been ongoing to discuss about re-naturalising the nearby creeks:

> "*So what we're moving towards is back to the natural, trying to reshape the creeks where possible and restore the natural flow so … that way it curves and [has] rocks and so forth that will actually absorb some of that flow and maybe slow it down a little bit …" (B1)*

The Oxley Creek Transformation Project (as described in Chapter 6) can be considered as Brisbane's biggest revitalisation project, with financial support from the BCC across a 20-year period. B1 shared that Oxley Creek was recently identified two years ago as a suitable location to initiate this "*visionary project*", which was to restore the natural habitat in the often-flooded Oxley Creek catchment from its industrial use. A key concept was also to engage people with the natural environment while also making it a functional place for biodiversity, recreation, connectivity and tourism (C1). B1 stated that beyond what has been planned in the Project, it was important to also concurrently restore the smaller creeks connecting to Oxley Creek:

> "*What I argue is the tributaries that go into that Stables Swamp Creek, Rocky Waterholes Creek, Blunder Creek ... we need to be actioning them at the same time while this Oxley Creek [restoration project] is happening. These side creeks that come into it that are affected so much, we need to be repairing and restoring and improving them as well. I haven't won that battle yet." (B1)*

C1 emphasised that through the Oxley Creek Transformation Project, it would enable "*room for natural systems to sit in [the] conversation"* concerning living on a floodplain and restoration of habitats and water patterns. The Project was able to take off due to changes in land use and "*a paradigm shift in management structure*", as explained by C1, where various local and state government individuals collaborated to formalise the Project through the establishment of a BCC subsidiary company with a funding mechanism and a budget to help streamline the works in the catchment. Additionally, B2 and C1 highlighted the strong stakeholder (including communities) engagement that provided input into the planning of the Project and utilised government resources as a springboard to develop the Project into a vision to be embraced by the community:

> *"The community needs to own and love it and use it and occupy and rent it and celebrate it." (C1)*

Another BCC-supported revitalisation project that was started by a community group, the Norman Creek Catchment Coordinating Committee, is the Norman Creek 2012-2031 Project. Along with other amenity-enhancing strategies, the Norman Creek Project incorporates BGI strategies to achieve one of its purposes of becoming a 'water smart', flood-resilient and nature-integrated catchment (BCC, 2013b). Stormwater harvesting, rainwater gardens, bioretention areas, natural channel designs, restoring concrete drains to natural creeks increasing riparian vegetation and school-initiated creek restoration programmes were described by B2 as some of the BGI approaches used in Norman Creek. C1 noted that Norman Creek Catchment Coordinating Committee was passionate, action-oriented and "*got the political ear of a local member to actually guide the process*" to developing and implementing the Norman Creek Project. A section of Norman Creek (formally industrial land) has been transformed into a park with basic amenities as the budget was mostly used on purchasing land, but it will still act as a trial site for other priority precincts of Stones Corner and Woolloongabba (C1).

B1 added that BGI and creek restorations are also topics covered in the BCC's Green Heart Fair (delivered in partnership with CitySmart) to help enhance the community's knowledge and awareness around the contribution of these measures to the Fair's aim of sustainable living. Although there are some significant BGI efforts, informants C3 and A6 found that BGI was not as widely implemented as ideally hoped for, indicating more can be done:

> *"If someone could draw where all the restoration work has happened in the last 10 years, you would have a feel but I know it would still be lucky to be more than 1% of the whole creek and river system and might even be less because [the system is] huge." (C3)*

Several informants (A5, A6, C1) identified that successful BGI projects like Oxley Creek Transformation and Norman Creek, that largely utilise natural features and systems to manage flood risks and provide concurrent benefits, had strong community backing and actively worked to gain government support for their vision. The projects were also sustained if they were well-embraced by the community to deliver the projects over the long-term. Other BGI type-work were described by informants (A5, A6, C1 and C3) to have taken place in the neighbouring areas outside of Brisbane or by independent organisations and consultancies. The findings from informants indicate a growing BGI scene, albeit slow, with the potential for BGI efforts to be increased in the future.

8.2 Issues Impacting Flood Risk Management in Brisbane

The interview findings revealed that beyond the existing flood risk management approaches, there are key issues revolving around the actors and the processes within flood risk management placing pressure on the overall effectiveness of flood risk management.

8.2.1 Perception of Risk and Risk Literacy

A number of informants raised their concerns over Brisbane inhabitants' understanding of risk, wherein the general public had a low level of risk literacy compared to professionals and practitioners. As demonstrated in Chapter 6, risk perception is mainly described in the national level strategic documents, and there is less to none in the state and local level documents. Many informants (A1, A2, A3, A5, A8, C2) observed that the public's lack of a detailed understanding of risk indicates that technical jargon within planning processes have not been presented in a way that laymen can grasp and apply to their everyday lives; this is further explained through selected comments in Table 8.4 below.

Table 8.4 *Comments on Flood Risk Perception*

"*And people don't understand risk. That's part of the problem. And also those maps and so on that they hand out, are not immediately obvious to people. I think there's a disconnect between the technological language and layman's language. If you say to me, 'Oxley's going to flood 19 metres,' I can't even conceptualise that. I can't, in my head work out what 19 metres even looks like. But if you said to me, 'The Jindalee Bridge is going to be on the water,' I get that." (A5)*
"So there's been this, kind of this, issue of people, when they buy places, often don't think about 'is this a flood risk'? They see a place and think 'Oh I love this place, I can afford it. It's located close to the schools or easy to get to work and you know, it's got a nice garden. It's exactly what I want. They don't think, is this in a flood zone, or it's in a bushfire zone, or is this in the land slippage zone. That's not what they think about. So, councils can put out flood mapping, they can put out bushfire risk mapping, which they do, but very rarely do people think about." (A1)

Note. Informants' comments on general risk perception around flood risks.

Due to the general level of risk perception held by the public, the BCC experiences further challenges in communicating the urgency of risk before and after flood events. As recounted by A5 who was aware that residents were not able to comprehend the amount of risk they were exposed to even when they were issued warnings, until the 2011 floods happened. This challenge is highlighted by A3, who referred to Peter Sandman's topology of risk communication that identifies how people react to hazards to determine appropriate methods of conveying risk information:

> *"The Sandman kind of topology of risk, hazard plus outrage, is you've got a situation where people might be at high risk, but they're not actually very worried about it. In fact, that's a very difficult risk communication challenge ... The one that gets a lot of attention is the 'it's not very risky, but people are outraged about it'. And governments have to deal with a lot of that. What the kind of preeminent risk communication experts in the world always says that it's the high risk but low outrage or low concern situation that is actually the hardest and most challenging." (A3)*

Informant A1 stressed upon the need to ascertain the level of risk that the people are prepared to accept, which is a challenge for the BCC to undertake. Informant A5 noted that even after living through floods, some people believed that they could deal with future floods, indicating the willingness to undertake a higher level of risk. This is particularly the case for those of a higher socio-economic background, as explained by A5, where those who are financially stable and middle-aged, are likely in a better position to recover from flood damage as compared to those who might lack of a stable income or are renting. The level of risk is not solely the responsibility of the BCC; developers and the community are also major decision-makers in the level of risk that they are willing to accept, as it affects the building, selling and purchasing of properties in risky areas along with property prices and insurance coverage. A1 noted the conflict that local councils may encounter with the public and developers in relation to restricting developments:

> *"So, there's this real difficulty, dilemma that local councils are in in terms of approving developments, particularly in low lying and flood prone areas. Because of that, because on the one side, they might get sued by the developer if they don't let the thing go ahead. On the other side, they might get sued by the residents if they wind up getting flooded out several times." (A1)*

The level of risk that the BCC is willing to undertake was noted through C2's observation that the BCC has still allowed developments in high-risk flood zones, for example, West End, Woolloongabba and Brisbane Central Business District. Low flood risk perception was observed by the informant to be likely a result of the BCC's concern that flood risk would impact upon property prices. C2 stressed on the lack of publicly available risk performance indicators in Brisbane and SEQ to track the rate of exposure to floods for planning:

> *"And nobody is quantifying risks. Nobody's reporting on their risks. Nobody's disclosing what their risks are. So, nobody in southeast Queensland says, 'How many properties are exposed to a flood risk? And are we tracking that every year?' There's no key performance indicators." (C2)*

Informants (A1, A2, A3, A8 and B1) emphasised the severe lack of risk literacy around floods (and other disasters) and the importance of understanding the inevitability of flooding in Brisbane due to its exposure to climate extremes. As it is impractical to assume that floods can be prevented, perceptions should instead be shifted to building scientific understanding in all levels of society on the significance of flood risks, the susceptibility of places and the level of risk willing to be undertaken. A1 highlighted the need to improve prevention and preparation for disasters such as floods, suggesting that developers should be given accurate information about flood risks and supported in building with suitable controls, which would allow them to build better flood-resilient buildings in compliance with the BCC's planning framework. This is supported by A4 and A8, who indicated that the BCC should be meticulous about planning and flood risk management when developing in vulnerable areas as it involves potential lives impacted or lost due to the statistical difficulties around predicting the next big flood.

8.2.2 Flood Memory and Attitudes

The cultural flood memory is a factor that affects the ways in which people understand and accept risk. Informants A4 and C1 observed that those who have lived through the floods of 2011 and 1974, would have developed a learned and lived experience that might persuade them to take the necessary precautions against future floods. Flood markers were observed around the Brisbane by several informants (A3, A6, C1 and C2) as a visual reminder to of the 1974 floods and as a turning point of Brisbane's relationship with the river. These experiences allowed the development of an "*enhanced awareness*" towards floods and climate change, potentially providing the community with "*social capital*" that they could utilise for future emergency responses (A4).

Many informants (A1, A2, A3, A5, A6 and A8) argued that this flood memory may be short-lived, where large floods were perceived by some of the population to be a singular, short-term event that they recover and move on from, especially if they have an attachment to their houses and communities. With the rapid growth of Brisbane, many new inhabitants who have not experienced floods, or are short-term visitors, particularly lack a cultural flood memory, affecting their flood risk literacy, flood responses, and choices of building and purchasing properties, as shared by A1 and A5. Moreover, the views of some informants (A3, A6 and A8) suggested that there are agnotological and political intentions around the collective flood memory, where the short-lived flood memory or the intentional fading of memory allows political and economic motives to take precedence; A6 (Urban Water Management and Policy Academic) recalled the BCC permitting the reconstruction of houses and subdivision of lots on land that was severely inundated during the 1974 floods. A3 speculated that the government and developers were concerned that the flood memory would impact on the financial viability of businesses and prices of real estate, leading to "almost an effort for a kind of collective forgetting of the event".

As the flood memory may be short-lived, A1 stressed that there exists "a window of opportunity" to make tangible changes right after a major disaster has occurred; A2 shared the same view. An example of this was the federal government eventually approving the reconstruction of more flood-resilient and disaster-resilient infrastructure, as the QRA identified that it would reduce risk and better withstand disasters in future (A1). Another example was the relocation of the town of Grantham in the Lockyer Valley, by the Lockyer Valley Regional Council to a higher hillside location after the 2011 floods (A1).

8.2.3 Deficiencies in Planning Processes and Decision-making

The 2011 floods were observed by informants B2 and A4 to have affected some change in how the BCC conducts flood risk management. B2 (Flood Policy and Planning Engineer) mentioned some strategies developed after the floods (*FloodSmart Future Strategy* 2012-2031 and *Brisbane. Clean, Green, Sustainable 2017-2031*) that encourage the adopting BGI-type strategies such as WSUD in planning and designing of stormwater infrastructure and amenities to manage flood risk. An element of adaptation at the government level, has been noted by informant A4:

> *"[The] more institutions like Seqwater and Brisbane City Council are exposed to contrasting extremes, the more adaptable they become. The old adage 'exposure breeds resilience' has some truth to it, I believe." (A4)*

B1 explained that even with the large amount of public complaints in regard to flood damage, the BCC still needed to be reasonable about its capacity to provide solutions. In that manner, the informant believed that the purchase of land that floods regularly, by the BCC, was an important measure as these areas should not be available for any residential or commercial development, not merely in the short-term but also over the next 20-50 years. Another example of the BCC making policy changes in planning, albeit gradual, was shared by C1:

> *"*Buildings that Breathe *is a document that Brisbane City Council has put out that looks to ensure that every new medium to high density project is giving back but at a social and environmental level. So, we are seeing green shoots of policy change … [it's] glacial, that never happens as quickly as we like. So, we tend to use that project to try and push for change both on the site [and] at a policy scale as well." (C1)*

Conscious planning for development and flood-aware planning is imperative for Brisbane**.** To prepare for Brisbane's future population growth, several informants (C1, A4 and A5) supported increasing density, in areas with minimal or no flood risk, through high-rises that concurrently contributes to environmental values over expansion of the urban footprint. Many informants (A4, A5, A8, B1 and C2) shared concerns over BCC's planning and decision-making processes to rezone city centre locations (flood zones) such as West End, and to allow the construction of high-rise apartment blocks in those flood-prone areas.

> *"Areas that flood frequently, so like Coorparoo ... and we're building high rises here, so I think some of that concerns me. [And that] is how I appreciate you can do some good development in areas of flooding, but I wouldn't put a lot of people there. Some people there, but you wouldn't put a whole lot, you know, a whole high rise of people in areas that flood." (B1)*

Furthermore, informant A4 and A8 pointed out the apparent lack of clearer controls in flood risk management provisions in the *Brisbane City Plan 2014*, indicating that more specificity could be introduced to guide developments on ways to adequately address flood risks:

> *"The provisions for flood risk management or for flood protection, the requirements are fairly big in the Brisbane City Plan in 2014, from what I've seen ... but it seems fairly vague, particularly since they've sort of gotten rid of – they have flood maps, but it seems to be sort of bordering on one side of 'less they share', 'Do It Yourself', sort of here are the maps and go forth and put in whatever protections you think are necessary." (A4)*

A2 also noted the "*massive institutional inertia*" that governments face when wanting to shift towards an interdisciplinary view towards different sectors in planning and the difficulty experts have in communicating uncertainty, hence adaptive management could be useful. Through the comments shared by the informants, it can be seen that since the 2011 floods, there have been gradual changes within the policy and planning processes to try to improve the way the BCC manages flood risks. Although there have been improvements, it is apparent that several deficiencies in the planning processes and decision-making might impede upon positive changes. Targeted flood-aware planning approaches to increasing density in appropriate locations and the reduction of development in high risk areas would contribute to better resilience. Moreover, transparency and specificity in guidelines are areas that need to be worked on within the planning processes and frameworks.

8.2.4 Pressures from Vested Interests

A major constraint on the BCC's planning processes is the pressure from developers' interests, as identified by many informants (A1, A5, A6, A8, B1 and C2). The concept of path dependency, as identified by A4, still persists through established institutional decision-making and development processes, where "*the idea of complete transformation or abandoning it is both publicly, deeply unappealing and also technically difficult as well*." The prevailing institutional and cultural mindset favouring development creates difficulties for well-meaning planners and government officials to make firmer decisions around development regulations to reduce exposure to floods and preserve the natural environment. Key comments expressing this sentiment are in Table 8.5.

Table 8.5 *Comments on Developer Pressure on Brisbane City Council's Planning Processes*

"The politics of it is quite difficult because in Queensland it's a very pro-development state with a rapidly growing population. Developers hold a lot of political sway … And they don't bear any responsibility because they build the development. They sell it off, and they've got no further interest in it, and often the company they've formed to do the development is then disbanded, so there's no one to sue if it's built in a flood prone area." (A1)
"There's a lot of really good planners in Brisbane and Ipswich who are aware of this who are trying to deal with it because they've got hearts. I think they know the problem, and systemic changes really hard, cultural changes, probably even harder. And that's what we're talking about. Changing an entire mindset has been pretty strong 200 years." (A5)
"But it's also constrained by the elected members in some of the executive teams because of the developer interests, and traditionally, planners used to be visionaries and planners would - we used to do strategic thinking and long-term planning. And we don't do that anymore. So, planners in Australia have been whittled down to become from what I think is little more than bureaucrats that kind of tick the box against a strategic claim document that's not very strategic." (C2)

Note. Informants' comments on the pressure from developers on Brisbane City Council's planning processes.

Conflicts within planning arise due to pressure from developers, whose motivations tend to be more profit-driven than in the interest of the public, as observed by C2 and A6. One example lies in the omission to release BCC's flood maps prior to the 2011 floods. C2 speculated that had this occurred, too many areas at risk would have been established, which were a result of previous decisions to permit property development in flood zones and a lack of climate change consideration. As property values may be impacted by this, C2 indicated that this would be a concern for the BCC as it may then "*affect the variable income, [because] how they get their income is by rates*". Additionally, the economic benefit from investments and the political support offered by developers can hold great leverage over development decisions over planning for natural hazards (C2, A5, A6 and A8). Several informants (A1, A2, A3 and A5) also highlighted the further conflict that occurs when developments are inundated or damaged by floods, leading to a shifting of responsibility to the government for having permitted building in flood-prone locations. A1 and A3 indicated that this shifting of responsibility is worsened when Council is expected to deal with the situation but lacks resources from the state and federal government as flood risk management is largely deemed as a local-level responsibility.

> *"And then after events like this, there's often an outcry saying to the urban planners 'Why did you let us build here,' and they say back, "Well, because the Premier, and the Mayor, and the local council said, 'We want this development to go ahead because it's going to create jobs, it's going to bring in tax revenue, it's going to be good.' And if we don't let people develop these areas, then there's going to be a shortage of land and the price housing will go up." So, we've got this conflict: we've got the politics and economics of this working against good risk management practices." (A1)*

C2 stated that the state government's interests are another major constraint affecting BCC's planning processes due to its legislative powers over BCC's planning scheme. State and local government policies were perceived to be outdated by C2, due to the prior lack of and late inclusion of climate change perturbations into flood risk management strategies, As shown in the Chapters 4 and 6, the Queensland Government has overarching powers over local government like the BCC and state legislation is reflected in the local planning scheme which sets policies that developments have to comply with; this is recognised by informants (B1, B2, A1, A5 and C2). A common view amongst some informants (A1, A5 and C2) is that the strong influence from developers could pressure the state government into making politically favourable decisions, and further complicate decision-making at the local level; as indicated in Table 8.6.

Table 8.6 *Comments on Queensland Government's Power on the Brisbane City Council*

"And so there's also a disconnect, there's been a devolution of responsibility to local governments, but they don't have the capacity to raise revenue, they can't do local taxes, they can only borrow off the State Treasury, and all of their land use planning mechanisms have to get approved by the state government. So, it is still really heavily influenced by state development." (C2)
"I know there's another development site owned by the state government. And it was an area that flooded quite frequently called Tennyson ... it's where the Tennis Centre is. And the state government has given it to a private developer to develop as a high-density zone ... so not everything is perfect." (B1)

Note. Informants' comments on the impact of Queensland Government's powers on the Brisbane City Council.

As seen in Chapter 4 (Brisbane Context), the Queensland Government was shown to have legislative authority over the BCC. Although BCC has been shown in section 8.1.6 (Blue-green Infrastructure Efforts) and Chapter 6 to have good initiatives, including that of BGI (Oxley Creek Transformation and Norman Creek Project), the informants reaffirm that the Queensland Government's institutional structure and powers constrain the BCC's planning processes, financial capacity and resources, which then impacts upon the BCC's decision-making in flood risk management and development.

8.2.5 Vested Interests and Funding Issues for BGI

Similar to the flood risk management, the use of BGI can also be entangled in vested interests which may require a change in mindsets and institutional frameworks. C1 noted that the Norman Creek Project had tricky issues due to the federal, state and local electoral boundaries that lie within the catchment, which could impact on the delivery of the Project. This issue would also affect other catchments that may have overlapping ownership from a combination of state and local government land, as explained by C1, "*So, it's a classic example of the ...*

geo-political planning construct being totally ignorant of natural systems extents." Informants also recognised funding as an issue that affects the delivery of BGI projects, wherein alternative sources of revenue may need to be generated (C1), or that the Council may prefer to allocate funding to larger projects due to larger community benefits and the political support it could potentially generate (A5):

> "*So, programs like green revegetation programs or cleaning up creeks, are potentially far more appealing to a council, because it'll help a lot more people ... whereas [if] you could clean up Oxley Creek catchments, you get 30 votes or 500 votes*." (A5)

In reflecting on their experience at Council, B1 noted that Council lacks in some areas but generally delivers reasonable outcomes with the amount of manpower they have and "*on the ground resources*". There is still a broad perception that as the largest Australian Council, BCC generates significant revenue from rates, as summarised by A5 who believed that BCC had the potential to "*do a whole-of-Brisbane solution*". The informant noted that there was a perception that this economic base was "*one of the strengths we've got. But we haven't. I don't know why.*"

This issue was touched upon in Chapter 4 (Brisbane Context), where little research apart from that conducted by Sinnewe *et al*. (2015), has been done on how BCC's size affects its performance. BCC's size may not necessarily correlate with its financial performance, as indicated by the research, due to the operations and priorities of its institutional structure. A1 reaffirmed the resource constraints of councils, particularly the BCC. The informant offered an explanation to this issue: rates do not necessarily result in sizeable revenue, where the amount of revenue obtained would need to be spent on maintaining essential services and facilities, and funding community organisations. Hence, such expenditure adds significant strain on BCC's resources, making it challenging for Council to provide more effort and resources into alternative types of management practices. The Queensland Government's legislative powers as mentioned in section 8.2.4 (Pressure from Vested Interests), also has relevance to the BCC's decision-making around planning for BGI. Brisbane's existing BGI projects (creek regeneration) appear to largely be implemented at the local level however, the fiscal and resource limitations of the BCC, as reflected by research and the informants, hinder the BCC's capacity in continuing such projects and other forms of BGI initiatives.

8.2.6 Planning and Maintenance Issues for BGI

Barriers to successful BGI integration in planning, as highlighted by C3, would be the development of "cost-effective designs", their implementation and demonstrating the measures' effectiveness to garner acceptance for BGI as a useful and well-founded solution. The acceptance of BGI within planning processes might affected by path dependence (section 8.2.4 Pressure from Vested Interests) for grey stormwater infrastructure (A5). Additionally, Council has to meet the *State Planning Policy's* targets, where BGI strategies may be prioritised for other targets over flood risk management within a tight timeframe (A2). Informant B2 believed that Council's undertaking of BGI strategies was community-driven, stating that "*it's not purely a cost-benefit scenario because [the BCC] is a public organisation, we are not operated for a profit*". Informants (A6, B2 and C3) indicated that a definitive cost-benefit analysis that could model the returns from BGI strategies is still lacking but A7 suggested that cost-benefit analyses are still useful to ascertain the costs of building and maintaining the infrastructure.

Another issue is when staff have the technical expertise but lacked the skills to communicate the benefits to people, A6 explained, "*… you can't articulate properly, why it is that a wetland does a better job than that water treatment plant down there*." This also affects the long-term maintenance needed for some BGI measures such as wetlands, where resistance from staff may occur from the lack of knowledge on proper maintenance (A3). Alongside the increase in developments and impervious surfaces, C2 and A6 argued that the inclusion of BGI can become tokenistic; "*it looks good in a planning mechanism, you can tick the box and say that you've got it*" (C2). Another issue is the lack of clarity around responsibilities of BGI implementation and maintenance, where "*sometimes [it is being] advocated by the environment department, owned by the asset management department or advocated by the planning [department]*" (C2), or when some developers meet the minimum standards of building BGI measures before transferring the maintenance responsibilities over to Council. Maintenance can also be affected by the lack of funding, which may lead to the failure of these measures (A7).

8.3 Learnings for Flood Risk Management in Brisbane

8.3.1 Views on Planning with Blue-Green Infrastructure

In reflecting upon the role of BGI in flood risk management, B2 shared that BGI would be more effective at reducing smaller, frequently recurring floods (1 in 2 – 20 year flood return period) compared to large floods with higher velocities and volumes (1 in 50 – 100 year flood return period) that would inundate or ruin BGI measures. A8 and A9 agreed with this view, explaining that runoff would not be reduced if soils were fully saturated from large volumes of water. Pairing BGI with grey infrastructure would be helpful in retaining water and reducing the impacts from floods, particularly in small-scale floods such as overland flow and creek flooding (B2, A5 and A9). The context-specific feasibility for BGI is shared below:

> *"[The] 2011 flood event brought like about 10,000 cubic meters of water per second; so, green infrastructure is not going to stand that amount of load. You will see all those rainwater gardens or anything else like that, being washed away. But one thing you can do, where the green infrastructure will help, is manage the sort of smaller-scale events. It might be a 2-year, 5-year, 10-year type event. Where you can apply them in smaller tributaries when overland flow comes and in creek catchments." (B2)*

Many informants strongly supported the inclusion of BGI within Brisbane's flood risk management approach to help reduce flow rates and increase infiltration, along with exploring its potential. Several informants shared examples of BGI approaches that could be applied in Brisbane (Table 8.7).

Table 8.7 *Comments on Blue-Green Infrastructure for Brisbane*

"... cleaning waterways to redivert the water ..." (A5)
"... retention dams to slow water up in the landscape ... vegetated keyline, contour banks' retention basin ... the riparian zone." (C3)

"… natural channels that meander, distributing their stress against much longer channel lengths and the gradient is lower as a consequence of having a longer reach. Natural channels dissipate energy extremely effectively." (A8)
"T*here's a lot of remediation being worked in some of the green spaces here, where they're replanting reeds, grasses and wetlands because those in a flood situation slow down the flow of water; overland water." (A1)*

Note. Informants' comments on types of Blue-Green Infrastructure approaches for Brisbane.

It is clear from the responses from informants that planning with BGI as part of the local flood risk management approach is a key factor to ensuring successful implementation. In general, informants were aware of the gradual transition of BCC's planning processes to more widespread incorporation and implementation of BGI. Although many informants wanted this process to be quicker, they acknowledged the various challenges, particularly within the governance landscape, that impede uptake. Indeed, successful integration of BGI strategies would require the deep consideration of infrastructure, flood risks, water supply, and adopting a holistic multi-scaled approach to planning, as indicated by several informants (A2, A6, C2 and C3), shown in Table 8.8.

Table 8.8 *Comments on Ways for Effective Integration of Blue-Green Infrastructure*

"And if you plan holistically and coherently then something like blue green infrastructure and nature-based solutions are so much easier to get people to accept because they're there from the start." (A6)
"It needs to go hand in hand with an integrated transport plan that has better public transport ridership. Okay, [for example] dig up half the roads, because at the moment we're a car-dependent city and roads are not the best for managing flood, I don't think [so], not at the scale that we get the water coming down." (C2)
"I think go back to planning, accepting the risks, so planning with water, designing to be with water. Making your towns floodable, so being designed so the water comes through…" (C2)

"But we need to put some of the natural infrastructure back in place to one protect us from the flooding, but also maintain the health of ecological health of the agricultural system." (C3)

Table 8.8. Informants' comments on ways to integrate Blue-Green Infrastructure effectively.

Combining BCC's technical capacity, along with strong leadership and visionary planning will help to bring a "*systems change"* that will elevate BGI integration (C2), however such an overhaul may be difficult to achieve. C2 and proposed the introduction of frameworks where Brisbane could "*be reimagined with living with water*", until there is "*the ability and capacity to change the planning scheme*", this sentiment is shared by C1. Other informants suggested the pairing of BGI strategies with robust development policies, having "*key indicators associated with the key climate drivers"* (C2), risk assessments (A1) and potentially the delivery of a higher liveability factor at a policy level cohesive with natural systems and new technology for living on a floodplain (C1). Integrated catchment-based planning was suggested by C1 and A9 as a large-scale approach, but C1 recognised the political issues relating to shifting electoral boundaries and the need for blending of social processes with natural systems processes at the local level. Several informants suggested incentives for the building of domestic rain gardens and site infiltration systems to "*stop the pit to pipe system*" which affects the creeks (C2), to encourage changes in decision-making for businesses and developers (A1 and C3) and to support farmers so that they are encouraged to restore riparian zones in upstream catchments while helping them keep productive country (C3).

The need for Brisbane to "*shift to a blue-green infrastructure city*" was apparent from C2. Informants (A4, A7, C2, C3) shared that wider awareness should be raised around the multiple ancillary benefits that it can offer along with managing flood risk, as it would help improve the reception of BGI strategies. Along with reducing flood risks, informants listed other benefits such as improving water quality (C3), decreasing the heat island effect (C2), allowing flora and fauna to flourish (A4), and recreational and health benefits (A7). As explained in section 8.2.5 (Challenges for Blue-Green Infrastructure), demonstrating the benefits of BGI would be a way of garnering support at various levels of society, particularly at the government level. It may be easier to promote projects to alleviate creek flooding than river flooding as they occur more frequently and would reduce flows into the river (A5).

BGI efforts in Brisbane are currently small to mid-scale; A8 believed that smaller scale projects could be "*a practical way to go if you can demonstrate, for example, that each one has a percentage effect on runoff rates, then cumulatively there may be an impact*." C3 suggested that some simple modelling could indicate that "*if you bring all the riparian zones back in, which is a real high level ideal, then you reduce the level of the flooding impact downstream*" but it would require the conversion of modelling data into information for the general public. A6 and A9 supported the idea of providing sufficient space for the flow paths of waterways.

The nature of floods can make tracking and predictions complex and affect decision-making. C2 called for manageable risk indicators (for example, percentage of impervious surfaces changing, the percentage of runoff experienced, the number of homes exposed to flood risks over time), disclosing the risks to the public and the management strategies used, which would improve transparency in the BCC's decision-making. C2 was aware that this would mean being accountable to the risks and performances of flood risk management practices and while it would be very challenging from a political standpoint, it would bring in "*genuine community participation*" and set an example for developers to utilise their risk assessments.

8.3.2 Views on Stakeholder Awareness and Involvement in BGI

The informants frequently stressed in interviews that there is a need to improve the public and private sector understanding of the Brisbane River system and surrounding ecosystems. These includes "*hydrological rhythms*" (A5), the value of floodplains and the river system and their impacts on ecosystem functions (A8), as well as understanding the geography of the catchment and the inevitability of flooding (A1 and A6). Understanding the natural flow patterns and changing nature of rivers could help rethink the way land is used (A6). It is also important for people to understand how increased runoff generated from impervious surfaces combined with the increased gradient from concrete channels increases the flow rate and the sheer stress on the waterway, resulting in flooding (A5 and A8).

From the responses of these informants, it is clear that there has been a gradual increase in environmental appreciation, but stakeholders and the community still need to strengthen their foundational understanding of risks, geography and ecosystem functions. Involving people at various levels of society with the maintenance of BGI infrastructure and having an educational component such as signage that provides broad information about an infrastructure's functions will help people to feel invested in and maintain the infrastructure (A7).

In general, informants were supportive of community consultations for their potential to gather the community to raise awareness of flood risks and develop ways to address them. A4 emphasised the importance of avoiding tokenistic consultation, instead developing suitable consultation and framing the issues sensitively to "*the technical aspects of these issues, but also the political knowledge that politicians have to take on board with regard to the values and ideology of government*," along with other stakeholders involved. Knowing that everyone has different needs, B2 indicated that consultation is "*... about balancing the better outcomes, balancing the ideas and bringing about the outcome for the majority of the public*".

Some informants (A3, C2 and B1) pointed out the importance of considering the capacity, skillset, understanding and priorities of people in various socio-economic positions, when determining the level of public engagement and involvement needed. A3 considered the public's general understanding of technical issues of flooding and suggested that participatory and deliberative processes could be creatively designed, for example, in the style of an expert forum to allow the community to discuss complex topics and gain insight from the experts. On the ground, an ideal level of public involvement would be when communities have stewardship (A9, B1 and C1), shown in the Oxley Creek Transformation Project (C2), to improve overall socio-ecological resilience (A9). In such a case, B1 noted that for elected Council members who are truly involved with their community, they will then be able to support alongside and undertake separate responsibilities while working towards the same goal.

8.3.3 Views on Partnerships and Resource Integration for BGI

Partnerships with other governments and agencies that function within the Brisbane River catchment were highly advocated by the informants (B2, A3, A1, A5, A7). A1 stated that identifying common interests, featuring the overall potential benefits that could be acquired and framing it in the other party's language, will contribute to successful partnerships and collaborations. The informant noted that this would require a "*governance approach rather than government approach*" where "*good relationships of trust*" established amongst various stakeholders, for example Noosa Shire Council's good relationship with community groups.

The provision of grants can also help to encourage the generation of fresh ideas and support them in delivery (A1). The view on partnership is summarised below:

> *"If you can get state government agencies working with local councils … if you can get other interested bodies involved in it. So, the Volunteer Services, the universities to help provide some of the knowledge and research [then] local councils can improve their capacity to do things in and out. And also getting local business on site." (A1)*

Informants highlighted that the integration of skills and resources can also build strong partnerships, which is useful for flood risk management and for implementing BGI. In terms of BCC's current integration of resources, B2 indicated that the Council has a good level of integration disseminated across various skilled experts (such as engineers, planners, communication experts, project managers and politicians) and resources (such as communications, mapping, funding and infrastructure) to supply various solutions for floods. Council also collaborates with local research institutes to investigate issues and solutions (A1). However, other informants did note the need for more integration; A1 and A7 recommended bridging the gap amongst experts, policy makers, academics and community members possibly through a platform for these individuals to exchange perspectives, deliberate over issues and brainstorm new solutions.

8.3.4 Views Comparing Flood Risk Management and BGI in Singapore to Brisbane

8.3.4.1 Governance and Planning Approach

Singapore's centralised governance approach, disciplined culture and shift to embrace planning (addressed in the Chapter 5) were emphasised by several informants (A1, A5, A8, C2) to be key factors in developing Singapore's robust planning processes and flood risk management approach. A8 highlighted that Singapore's past existential threats and socio-economic state were strong reasons as to why "*Singaporeans put up with planning because there was every good reason to do it,"* recalling how the Bukit Timah canal was built to deal with the major floods of 1950-1960s. The informant stated that these floods were "… *devastating and that was* *an existential issue for people living there,*" particularly since public housing blocks were only established from the 1960s.

A8 indicated that the development of high-rise public housing had merit in the initial planning of Singapore's flood risk management approach, as it allowed the government to plan for housing alongside flood risk; with future developments and upgrades of housing estates resulting in "*almost a green corridor between the high rise and [the] channel*". Moreover, the informant highlighted Lee Kuan Yew's vision of 'A City in a Garden' (reflected in the *Master Plan 2019*) and one of the early planners who acknowledged the imperative to deal with floods, as examples of visionary leadership and proactive planning to be crucial in driving Singapore's urban planning and flood risk management approach of today:

> *"And again, Singapore planned. I remember seeing a television program when I was living in Singapore, one of the early planners and he was a very intelligent man. He just set out the principles that they formulated, and Lee Kuan Yew agreed to it. I mean Lee Kuan Yew, he was basically 'it' for years, in terms of decision-making. [But for planning] I think it probably is quite sensible ... In these days, of course, you'd then need to work out whether that's sensible from the perspective of utilities, with power and water, sewage, rubbish." (A8)*

Similarly, A5 believed that Singapore has been more advanced in its flood risk management compared to Brisbane because the Singapore government conceded early on that they had flooding issues while "… *Brisbane's got to admit they've got a problem to start with* ...". This comment is perhaps a reflection of the more individualistic Australian culture that has a "healthy cynicism" (A2) of the government, which can make efforts somewhat challenging when persuading Australians to be more proactive in dealing with hazards (A1). Singapore's governance style has influenced, if not integrated into, its long-term planning, this was summarised by C2:

"… some people might argue in Singapore, you'll have benevolent sort of dictatorship style, where it's a bit easier, but at least in Singapore, you do strategic thinking and you look at scenario development, you look at big long term issues and mega trends how that [is] reflected back?" (C2)

The cultural governance differences between Australian and Singapore were highlighted by informants. Brisbane's government (and Australia in general) was perceived to be more "*community-driven and government-reactive*" (A5) while Singapore's government was more proactive and technocratic (A2, A5, A7 and A9). A6 and A7 (Hydrologist and Academic) commended the Singapore government's political will and institutional efficiency in adopting new concepts, rectifying mistakes, and willingness to invest in innovation:

"It's deadly committed, when it makes a serious mistake, it goes, 'Oh, hang on that actually was the wrong thing to do. We won't do that again'. I really like that. And in many ways, in spite of all the data [and] information that you can't get, it almost makes up for all that, because [of] the political will [and] the financial capacity. And even within the bounds of being a government project, a little bit of innovation, a little bit of flexibility, a little bit of adaptability." (A6)

A7 and A9 appreciated Australia's preference to engage in open discussions during project consultations but noted the time-consuming process taken to come to a consensus with different opinions. Conversely, the Singapore system, even with consultations, has a more directive approach to it (A7). However, A8 noted a change in Singapore's governance approach, alluding it to the shift in leadership from Lee Kuan Yew to his son and current Prime Minister, Lee Hsien Loong. The informant further explained that the government has been trying to ascertain if the ABC Waters Programme was providing benefits to the locals, "*They really want to connect to the people not just tell them what to do*". Informants (A6, A7 and A9) also noted that the lifespan of projects and security of funding were affected by periodic rotations in the governing party within the Australian government, whereas Singapore's de facto one-party system provides more stability in projects and funding. Multi-agency collaborations were another reason for Singapore's successful integration of BGI through the ABC Waters Programme (A7). Interestingly, A6 observed that Singapore's journey to provide effective flood risk management to mitigate big floods now reduces the community's resilience to living with floods, and warned that "*creating this notion that it is flood proof, you completely train out that resilience, the skills, the expertise of living with floods*".

B2 believed that BCC's political willpower allowed it to establish various flood risk management and BGI strategies beyond the planning stages. Additionally, B1 referred to a Queensland legislation, the Prohibited Donors Scheme, that prevents the Queensland Government from accepting developers' donations, but noted that developers' lobbies still hold a lot of power. However, many informants expressed the wish for the BCC and the Queensland Government to be politically courageous against developers' interests in their decision-making and more towards the community's interests (A5, A6, A8 and C2), along with having more initiative in innovation (C1). Furthermore, A6 felt that Brisbane was still reluctant to fully embrace re-naturalisation and riparian zone rehabilitation citing its preference to install amenity features that seem have flood mitigation functions (such as boardwalks) instead. A9 suggested that Singapore's gradual shift from "*a whole-of-government approach to a whole-of-nation* approach" towards governance is a big move that other governments, like the BCC, could learn from as it embraces top-down and bottom-up processes.

8.3.4.2 BGI in Flood Risk Management

Singapore has been perceived by informants (A1, A5, A7, A8) to have been successful at high-density urban planning and the holistic integration of BGI strategies to support current grey infrastructure. The integrated approach to BGI has been a result of broader thinking, a multidisciplinary effort amongst various experts and continual maintenance (A7). A5 supported the idea of Singapore being a good case study for Brisbane, due to the closeness in climates and flooding experiences within an urban environment. Singapore's flow rates are notably lower than Brisbane's, based on catchment size rather than from rainfall, hence it would be more reasonable to compare Brisbane's tributaries to Singapore's waterways, as the flow rate of the Brisbane River would be too great (A8).

Informants (A6, A8, A9) praised the ABC Waters Programme as part of Singapore's flood risk management, particularly with its capability to provide other environmental and amenity enhancing functions. A8 recognised the multi-functionality of the Programme, which provides amenity, ecological and recreational benefits in addition to flood risk management. Having seen posters of Kallang River in Bishan-Ang Mo Kio Park as a recreational destination with plenty of people and biodiversity actively using the waterways, the informant felt that because of Singapore's compactness, this programme was "*actually quite important, it should involve people*", musing that Singapore has "*got that right*". Similarly, A6 approved of the Kallang River naturalisation within Bishan Ang Mo Kio Park, which allows the river to expand beyond its banks when it rains, with suitable infrastructure "*that remains regardless of the water state*". A6 and A7 noted that Bishan Ang Mo Kio Park also functions as a multifunctional community space that contains community vegetable patches, an educational hotspot for schools' outdoor classes and community clean-ups. In that respect, A6 highlighted that more adaptability in Brisbane is needed through a shift in "*the way we live, the way we develop and the way we can value things in an urban environment,*" particularly towards BGI measures:

> *"So, they might get washed out, it's only a community veggie patch. It's not your whole wheat industry, is it? No, it's a community garden. It can be washed away, you replant six months later, you've got food." (A6)*

A9 (Civil and Environmental Engineering Academic) felt that the Programme replicated WSUD principles well, since its guidelines were "*inspired by Australian regulations*" and technology and knowledge sharing from Melbourne to Singapore occurred (addressed in Chapter 5 – Singapore Context). Additionally, A6 felt that "*almost any city in Australia can learn from ABC waters [Programme]*". A9 pointed that the approach taken by the Cooperative Research Centre for Water Sensitive Cities in Brisbane and other parts of Australia, was a paradigm shift example which encompasses BGI strategies in urban planning and design to improve water sensitivity in cities that mitigates flood risks and provides other socio-economic and ecological functions.

8.3.4.3 Public Communication and Involvement

Informants A6 and A8 felt that the Singapore government and PUB had effective systems for public relations and warning dissemination. A8 noted that "*you can even push out complicated, complex ideas and messages … and expect a lot of them to be understood*" because the young to middle-aged generation in Singapore are educated and tech-savvy; A6 shared this sentiment. A8 believed this to also be true in Australia but felt that the governments were not as proactive and ardent in disseminating risk information. A6 and A7 praised the signage established that explains the functions and features of projects under the ABC Waters Programme; "*You've got the really excellent signposting; you got the little Water Drop [sign] that goes 'this is a rain garden!' ... really good!"* (A6). The signage presents scientific information and prohibited behaviour in a concise manner suited to the attention span of passers-by (A6); this information was also shared by PUB on social media to engage with and inform the public of projects (A7). In Brisbane however, A6 argued that such signage for BGI measures and the appreciation of the functionality and value of water is still lacking; A2 noted that the low investment needed to establish a small feature like signage could make a difference in improving public knowledge.

One disadvantage arising out of Singapore's governance style is the restrictions around access to certain information. A8 felt that the PUB had competent staff but acknowledged that they had to be "*very, very careful about what they do and say*" due to bureaucratic control over how information was used and shared; the informant also had trouble accessing any water-related research data. Similar sentiments were shared by A6, who contemplated the breadth of water-related information that was unavailable publicly. A6 recalled being unable to access data around the capacity of an in-channel wetland to pull out nitrates and phosphates, which was installed as part of the Pang Sua Pond upgrades under the ABC Waters Programme. Results, albeit positive, from the National University of Singapore were not allowed for release by PUB, likely hindering the continuation of the research, recalled A6. The informant, however, felt that there was more accessibility around data in Brisbane.

Some informants believed that community involvement in Singapore's flood risk management and BGI has a "*whole untapped potential*" (A6) and noted a growing grassroots scene in Singapore with increasing government efforts to improve participation, for example enabling the provision of feedback and engagement through 3D visualisation tools (A9). Being a small country and having a singular water authority, A6 felt that Singapore could learn and benefit from Australian community initiatives such as Waterwatch Australia (a citizen science network that monitors and rehabilitates local waterways) and catchment management programmes. Such community groups, perhaps with a supervisory board, government funding and training; can coordinate the undertaking of monitoring, site management or research tasks (A2 and A6). This will allow the PUB to obtain data and administer tasks with the help of volunteers, concurrently building community trust and provides the current generation (who may not have participated in the formation of the ABC Waters Programme or have experienced the major floods) with an opportunity to really understand and participate further in the ABC Waters Programme (A6). A6 and A7 emphasised on locals' curiosity about their waterways and their desire to be involved; A6 recalled conversations with locals about water and noted the locals' pride in the ABC Waters Programme, Marina Barrage and green spaces:

> "*You give them the capacity to get involved, they will, they generally do a good job, they give you the data you need, they learn what's going on. So, they understand the depth of information, the depth of need behind a thing like an ABC Waters programme.*" *(A6)*

8.4 Concluding Discussion

The results presented in this chapter addresses all three research questions as follows:

1. *How do Brisbane's and Singapore's planning processes contribute to the development of their flood risk management approaches?*

2. *What are the issues and limitations of Brisbane City Council's planning processes and infrastructure that affect flood risk management?*

3. *How and to what extent can blue-green infrastructure be used as a more resilient and sustainable option for flood risk management and what are the barriers to the implementation of this infrastructure?*

Through the key informants' interviews, it can be seen that informants were aware of a number of Council's flood risk management strategies. BCC informants tended to perceive the strategies used as effective while also acknowledging their limitations. Academic and consultant informants were more discerning in their critiques around the strategies, largely focusing on the need for more accuracy in mapping, better consideration of climate change and land use factors, more transparency through risk indicators tracking long-term flood risk, reducing overreliance on grey infrastructure, more clarity over scientific metrics (like the Q100) and providing more guidance to the public to make better flood-aware decisions. BCC informants highlighted BCC's growing efforts in embracing and implementing BGI, which were also recognised by some academic and consultant informants. Through their views, there appears to be good potential for BGI implementation through passionate individuals in private practice and the community, whose local expertise and the ability to function at the local level can support the delivery of projects. Financial support and resources by the government are also seen to be crucial towards sustaining the longevity of these projects and supporting the groups delivering them, as shown through the Oxley Creek Transformation and the Norman Creek 2012-2031 Projects.

Academic and consultant informants highlighted several issues impacting the effectiveness of Brisbane's flood risk management: varying risk perceptions and risk literacies at all levels of society; and deficiencies in planning processes and decision-making that enable development in flood-prone areas and a lack of detailed flood risk management controls. Pressure from developers' and the state government's interests, where more priority is placed upon urban development over flood-aware planning and the State's legislative powers limiting the BCC's planning capacity, is another major issue identified by informants. Similarly, BGI in Brisbane experiences pressures from various institutional interests and is constrained by funding. Other barriers involve the implementation capacity, the need to definitively prove and communicate its effectiveness, and the lack of clarity around responsibilities of implementation and maintenance. Informants acknowledged the limitations of BGI, but highly advocated for the use of BGI in Brisbane's flood risk management, recommending a combination of BGI and grey infrastructure or context-specific applications, such as creek and overland flow rather than river flooding. A holistic multi-scaled approach with robust development policies, key climate indicators and risk assessments were suggested by academic and consultant informants to support successful implementation. Additionally, more emphasis should be placed upon improving stakeholder awareness and involvement and developing partnerships with other governments and relevant agencies to integrate and utilise different skills and resources.

Informants greatly supported the ABC Waters Programme undertaken by the government of Singapore for flood risk management and other social and environmental functions and agreed on the feasibility of using Singapore as a flood risk management and BGI case study for Brisbane. They acknowledged that the centralised governance approach and willingness to innovate had great impacts on the direction of urban planning, flood risk management and BGI integration in Singapore, and desired for BCC and other Australian governments to be more proactive. Noting the difference in flow rates between the Brisbane River catchment and Singapore, it was found that BGI strategies (modelling off of Singapore's BGI strategies) would be better suited for and adapted to Brisbane's creeks. Informants also hoped for more data transparency to help the Singaporean public build a deeper understanding of the government's endeavours, and especially pertaining to this research, the efforts in BGI and stormwater management to reduce flood risk. Additionally, there is a wish for more capacity to be given to civil society groups, and the young to middle-aged population, to engage and be involved in government projects. Conversely, Brisbane needed to establish a more efficient level of community engagement and address funding issues. Informants believed that the Singapore government's proactiveness and efficiency around information dissemination along with clear and concise signage, could be areas of improvement for Brisbane, with some suggesting that blending Singapore's active public relations and communication channels with Brisbane's active community engagement and involvement practices, could provide an effective system.

Furthermore, informants noted that since the ABC Waters Programme shared some roots with Melbourne's WSUD practices, there is capacity for transferability, where relevant strengths of the Programme could be adapted to suit the local Brisbane context. Overall, informants collectively indicated that identifying the strengths of Singapore and Brisbane's flood risk management and BGI practices could help the development of an effective model for Brisbane's flood risk management. Building upon the analysis of planning and policy documents that guide Brisbane's and Singapore's flood risk management and BGI from Chapters 6 and 7, findings from this chapter delved further into the effectiveness of Brisbane's strategies, issues within Brisbane's flood risk management and gleaned areas of learning from Singapore's integrated approach. The final Chapter 9 will summarise the key points from Chapters 1 – 3 and discuss the key findings from Chapter 4 – 8 in relation to literature to answer the research's objective and questions. The research will be concluded with lessons that Brisbane could undertake to improve its flood risk management and BGI approaches, areas of future research and final remarks.

9 Conclusions

9.1 Introduction

Floods are one of the most common hazards to occur around the world, especially for urban areas that are in proximity to riverine networks or experience severe wet weather events (UN-Habitat, 2015; Voskamp & Van de Ven, 2015). This has been an ongoing situation for the case studies of this thesis, Brisbane and Singapore, where the extensive impacts of floods can cause significant challenges for these location over the long term. Hence, it is crucial that flood risk management frameworks employ a range of structural and non-structural methods (Raadgever *et al.*, 2018) and utilise interdisciplinary and adaptable planning and policy approaches to manage and alleviate flood risks so as to minimise the impacts when floods occur. The thesis has demonstrated that for flood risk management to be effective, governments need to understand the nature of floods, flood history, geography and climate specific to the location within which floods transpire, in addition to an urban planning and governance environment that serious considers flood risks and prioritises actions to address these risk. The unpredictability and increasing severity of floods along with climate change is accompanied with a steady shift and understanding towards more sustainable practices in flood risk management such as the incorporation of Blue-Green Infrastructure (BGI).

This research explored the flood risk management strategies currently in place, most of which were precipitated by the 2011 Brisbane floods, in addition to exploring the potential for BGI to be a key flood risk management measure. To provide further insight on the areas that Brisbane's BGI implementation can be improved within its flood risk management framework, this research looks to Singapore as a best-practice case study of an integrated flood risk management approach that incorporates BGI. The research questions of this research are as follows:

1. *How do the planning processes of Brisbane and Singapore contribute to the development of their flood risk management approaches?*

2. *What are the issues and limitations of Brisbane City Council's planning processes and infrastructure that affect flood risk management?*

3. *How and to what extent can blue-green infrastructure be used as a more resilient and sustainable option for Brisbane's flood risk management and what are the barriers to the implementation of this infrastructure?*

The Literature Review in Chapter 2 provided an overall understanding of how common flood risk management strategies manage and mitigate flooding, the concept of BGI and the ways in which BGI is increasingly used as a flood risk management strategy. The literature demonstrated that due to the variable nature of floods and government priorities, there is no singular established flood risk management framework for governments to utilise. Rather, there are structural and non-structural measures that are grouped into strategies (wherein strategies are termed differently in different locations) of which governments will use any combination of strategies to develop a framework that suits their contexts.

These strategies and measures were ascertained based on the available research, forming an overall context of their functions and applications. This context helps to understand the rationale of the way flood risk management frameworks are developed by governments for mitigating flood risks. BGI was also addressed in the literature review to showcase how there has been a growing shift from grey infrastructure to more natural, sustainable and resilient infrastructure (and even combinations of grey infrastructure and BGI) towards managing flood risks. Through two international BGI examples in South Korea and China, it was shown that BGI applications are highly context-specific and their success is largely dependent on the robust and motivated governance and planning processes and steady financial investment to support the projects to completion. The adaptability of BGI is shown through these examples, which helped in understanding BGI implementation in Brisbane and Singapore.

The research methodology towards addressing the research's questions was described in Chapter 3, where a dual case study approach was utilised; primary research was conducted through 14 key informant interviews; and secondary research was carried out through policy and planning documents, government websites and visual materials. Some limitations arose from this research that impacted on the research and its results. These were the inability to travel to conduct face-to-face interviews and the limited time available to conduct primary research, a small sample of Brisbane City Council (BCC) key informants, and the lack of government agency key informants from Singapore, which limited to an extent the collection of data and further understanding of perspectives from both contexts. Despite that, the results obtained from online interviews of the available key informants still offered key insights to the ways in which flood risk management and BGI is conducted in Brisbane and Singapore. The BCC's current flood risk management measures were found to require increased accuracy and transparency, while challenges within governance and planning processes, development and socio-political pressures impact upon the effectiveness of the flood risk management framework and BGI implementation. While Brisbane and Singapore have different ways of undertaking flood risk management and BGI, nevertheless each case study demonstrates various strengths that can be transferrable to each other. Through discussions with key informants, a comprehensive analysis of the policy and planning documents and a review of the literature, it has allowed me to understand the research objective from various angles and triangulate the findings to answer the research questions.

9.2 Key Findings – Brisbane and Singapore Contexts

A contextual understanding of the primary and secondary case studies, Brisbane and Singapore respectively, was built in Chapters 4 and 5, detailing each case study's geographical-climatic factors, flood history, and the influence of the governance approach on planning processes, which in turn impacts upon flood risk management. These two chapters address Research

Question 1: '*How do the planning processes of Brisbane and Singapore contribute to the development of their flood risk management approaches?'* in part by providing a background to how planning processes work within the governance landscape in order to develop flood risk management frameworks and strategies.

In Australia, flood risk management is not handled at the national level, rather it is conducted at the state (Queensland) and local government level (Brisbane) (Burton, 2017). The overarching planning processes around flood risk management are provided by the Queensland Government, who also denote the BCC's responsibilities towards handling flood risk and regulates its policies (Burton, 2017). At the local level, the BCC provides specific flood risk management provisions that guide development and the implementation of measures that alleviate or manage flood risk. The BCC's responsibilities are generally noted to be clear, however the research finds that their planning and decision-making processes are seen to be somewhat ambiguous and limited by the complexity of institutional arrangements across government sectors and development pressures from the private sector. As mentioned in Chapter 4 (Brisbane Context), Sinnewe *et al*. (2015) found that despite being Australia's largest council, the BCC had less financial flexibility and resources than is generally perceived by the public, but good capacity for infrastructure provision. This multi-level institutional structure surrounding planning and governance in Brisbane, shows that different levels contribute to different capacities of managing flood risks. However, within these contours, the research found that this is not as effective as it could be, where tensions can arise around lack of clarity around governance responsibilities, constrained planning capacity, private sector's interests in development and the high priority placed on infrastructure. This means that sometimes flood risk management is not afforded as much priority as it should be considering how Brisbane is highly susceptible to floods.

In contrast, planning for flood risk in Singapore is only conducted at the national level by a government agency solely in charge of water, the Public Utilities Board. This approach is part of the country's centralised governance planning which plans for flood risks alongside other sectors such as water supply, housing and transport. This was done through the provision of a country-wide drainage network and an integrated stormwater approach, while also adopting BGI approaches (through the ABC Waters Programme) to not only improve the country's flood risk resilience but also provide other benefits for urban living. This approach was seen to be established through much trial and error and although it does not provide full protection from floods, the research observed that Singapore's approach has now managed to mitigate the intensity of floods from what was experienced in the past to a level that can be regulated and deal relatively efficiently by the government. Through these two chapters, the planning approaches undertaken for flood risk management in Brisbane and Singapore have thus contributed towards understanding the development of planning and policy documents from both case studies in Chapters 6 and 7.

9.3 Key Findings – Planning and Policy

Chapter 6 presents the relevant legislation, strategies and policies at varying levels of government around managing flood risks for Brisbane. This chapter follows on from the previous two chapters to answer Research Question 1: '*How do the planning processes of Brisbane and Singapore contribute to the development of their flood risk management approaches?'* wherein the planning processes of Brisbane's flood risk management systems can be further understood through the various strategic documents that guide flood risk management. Corresponding to the context in Chapter 4, flood risk management in Brisbane is seen to be largely addressed through strategic state-level and local level documents. Significant content overlap was found across the selected state-level documents, where many of them were formulated to provide guidance on developing implementation schemes to manage flood risks rather than defining specific actions for authorities to undertake. This content overlap demonstrates a lack of clarity around the distinct responsibilities of the relevant authorities, indicating a need for the Queensland Government to streamline their strategies so as to improve certainty and encourage action. Additionally, BGI is not widely incorporated in state-level documents; general strategies are supplied for documents that do include BGI. Highlighting the growing global attention on ecosystem-based strategies, Corotis (2018) suggests that such strategies should be properly contemplated within a wide-reaching regional strategy that takes into account the spatial requirements and robust land zoning rules that ecosystem strategies require so as to function optimally.

Local level documents, conversely, are much more explicit in their provisions and supply further technical details and information to guide users on development, flood risk preparation, and the short and long-term actions undertaken. In particular, BCC's documents reflected a strong emphasis on flood defence infrastructure to regulate and mitigate floods. However, the

BCC has shown a shift towards natural systems by embracing their functionality with their existing flood risk management framework and built infrastructure; this is seen through the significant provision of BGI through the *Brisbane City Plan 2014* to support their stormwater infrastructure, along with the community-driven *Oxley Creek Transformation Master Plan*. To compliment the approach taken in Chapter 6, Chapter 7 runs through the relevant legislative and strategic policy documents for managing flood risks in Singapore and provides a context to Singapore's planning processes in flood risk management for Research Question 1. Singapore was observed to have a more streamlined and centralised approach, with the documents providing detailed information on the integrated strategies used to manage stormwater so as to reduce flood risk nation-wide.

A comparative document analysis of Brisbane and Singapore is also contained within Chapter 7 to understand the choices of strategies chosen. Through the comparative analysis, a large variation in flood risk management strategies was noticed across the selected documents for Brisbane and Singapore, where some elected to utilise a single strategy, while others preferred a combination of strategies within their framework. The large variation indicates that flood risk management strategies chosen will differ based on their priorities and the planning and political governance environment, which is reflective of the literature in Chapter 2. This shows that there is no common framework towards managing flood risks, rather it is context specific. For example, Brisbane elects to use a larger combination of flood risk management strategies more so at the local level compared to the state and national level likely due to high level of planning responsibility held by the BCC to manage flood risks. Additionally, as Brisbane experiences a range of flood types (as addressed in Chapter 4), it is likely that a combination of strategies was chosen as a more comprehensive and resilient approach to regulating and alleviating flood risks. In comparison, as Singapore manages flood risks through a centralised approach that plans its stormwater infrastructure alongside other urban planning sectors, there is a clear preference for land use planning, building regulations, flood defence infrastructure and flood preparation strategies which would help streamline planning across the country and improve institutional efficiency towards dealing with future flood risks.

Also addressed within the document analysis of Chapter 7 is Research Question 3: '*How and to what extent can blue-green infrastructure be used as a more resilient and sustainable option for Brisbane's flood risk management and what are the barriers to the implementation of this infrastructure?*'. The analysis showed that BGI is not well considered at Australia's national and Queensland's state levels due to a primary focus on disaster management and regional development. A larger focus on BGI is seen at the local level of Brisbane, reflecting a higher capacity to plan and implement BGI strategies, with the most effective implementation (based on criteria determined through literature review) observed through the Master Plan of the community-driven and Council-supported Oxley Creek Transformation Project. In Singapore, flood risk management employs a holistic, integrated approach that incorporates BGI as a flood risk management strategy in addition to integrating it within its urban planning, allowing it to be consistently implemented on a national scale to support its existing stormwater infrastructure in alleviating floods while supplying ancillary benefits for its citizens. Moreover, the ABC Waters Programme is a nation-wide BGI approach that was developed to support flood risk management and improve liveability. A key feature of the Programme was its learnings from Melbourne's WSUD approach to adopt and adapt best practices for Singapore's local context, indicating the transferability of BGI to a different context. It is seen through the ABC Waters Programme that large-scale applications of BGI, especially for flood risk management, can be highly successful when well considered within urban planning as part of a city's growth and liveability and supported with comprehensive and succinct policy and planning documents. Although at present in Brisbane, it appears that BGI works more effectively at the creek-scale, there is much potential for BGI applications to expand throughout the city if given more consideration as a central part of the city's urban planning and flood risk management approach.

9.4 Key Findings – Semi-structured Interviews

Chapter 8 explored the findings of the key informant interviews, addressing all of the research questions in detail. For Research Question 2: '*What are the issues and limitations of Brisbane City Council's planning processes and infrastructure that affect flood risk management?*' the informants contrasted in their views concerning the effectiveness of the BCC's flood risk management strategies, wherein Council informants tended to deem the strategies to be effective to an extent while academic and consultant informants had distinct critiques around improving their effectiveness. These critiques are summarised as follows and demonstrates areas of improvement:

- Improving accuracy in the mapping of flood-prone areas;
- In-depth accounting for climate change and land use factors in planning;
- More transparency of flood risks by tracking long-term flood risks through risk indicators;
- Less dependency on solely using grey infrastructure to manage stormwater and flood risks;
- Improving clarity on the functions of scientific metrics in flood risk management;
- Providing better guidance in helping the public make flood-aware decisions around risk.

The issues above are all the more pertinent for thinking through Brisbane's future approaches, since climate change can cause levels of flood risk to fluctuate (Smith & McAlpine, 2014), hence communities should take pre-emptive measures against the possibility that flood mitigation infrastructure may fail (Corotis, 2018). This indicates that flood risk management strategies should not only be robust but also adaptable. In particular, all individuals affected should be provided with access to data used within decisions around risk (Corotis, 2018; Knorr & Scholze, 2008). As observed from the results, implications of a changing climate have only recently been incorporated in the flood risk management datasets of state and local governments, where past decisions around flood risks have now shifted in terms of accuracy, so reassessments would be required to provide governments and the public with more transparent and accurate information. Since uncertainty impacts the accuracy of information, Smith and McAlpine (2014) proposes that using a span of estimates for flood risks would be more robust than a singular value as flood events are variable. Additionally, the public should be made aware that the unpredictability presented by climate change would influence the robustness of technical data and will subsequently affect latter decision-making. As such, flood risk management programmes should actively include all stakeholders such as the public, developers, businesses and institutions who will be confronted with direct and indirect repercussions in the event flood infrastructure fails (Hegger *et al.*, 2018; Corotis, 2018). Keeping in mind climate unpredictability, experts and the public should work in partnership to alleviate possible floods impacts, which could help the community understand that damages experienced are not solely the fault of failed flood defence infrastructure, but also due to decisions around land use, building codes and the social views around development areas (Corotis, 2018; Hegger *et al.,* 2018).

The issues that impact upon the effectiveness of Brisbane's flood risk management (mainly highlighted by academic and consultant informants) and the challenges that hinder BGI implementation in Brisbane's flood risk management (highlighted by all informant groups) are summarised in Table 9.1.

Table 9.1 *Issues Affecting Flood Risk Management and Blue-Green Infrastructure Implementation in Brisbane.*

Issues impacting effectiveness of Brisbane's flood risk management	Issues impacting Blue-Green Infrastructure implementation within Brisbane's flood risk management
• Different levels of risk perception and risk literacy; • Varying flood memories and attitudes; • Deficiencies in planning and decision-making processes and where development is allowed in flood-prone areas and a lack of prescriptive flood risk management controls; • Development pressure from developers and the Queensland Government.	• Pressures from vested interests; • Funding constraints impacting implementation capacity; • Demonstrating effectiveness; • Lack of clarity around responsibilities of implementation and maintenance; • Poor communication of benefits; • Lack of political will, institutional efficiency and innovation.

Note. Key informant interview findings of the issues impacting the overall effectiveness of Brisbane's flood risk management and Blue-Green Infrastructure implementation within Brisbane's flood risk management.

This thesis has argued that there are both distinct and overlapping issues impacting the effectiveness of Brisbane flood risk management and the capacity of BGI to assist in enhancing that management. Some of these relate to varying levels of risk perception and literacy amongst different stakeholders whilst others stem from deficiencies in the planning and decision-making processes. Furthermore, implementation and maintenance of BGI is often lacking in clarity and relevant authorities do not clearly communicate the potential benefits of the implementation of this infrastructure. More generally, processes around flood risk management are problematised by vested interests who prioritise the economic benefits of property development and navigate around the current flood risk management controls. Additionally, flood risk management also faces challenges from low political will from the state and local governments to dedicate more efforts towards pursuing more innovative and sustainable ways to deal with flood risks.

Development pressure in Brisbane, as explained in the Chapter 4 (Brisbane Context), is a complex issue where the private sector's development interests complicate the state and local government's decisions within their planning processes (Gleeson *et al.*, 2010; Bajracharya & Khan, 2020). Similarly, this pressure is also found when planning for BGI. This is seen through the Queensland Government's legislative powers around development and institutional structure as mentioned in Chapter 8 (sections 1.2.4 and 1.2.5), which impact upon their financial capacity and resources and affect the BCC's planning and decision-making for flood risk management and BGI. Through the research, it should be noted that BCC's fiscal and resource limitations pose a threat to its capacity in continuing its existing creek regeneration projects and may hinder other forms of BGI initiatives in future. The interests of the property developers can be understood as being primarily "concerned with returns on investments" (Everett *et al.*, 2015, p. 59). However, developers that are conscious of their public reputation and Corporate Social Responsibility will be more willing to understand the capacity for BGI to provide value to their standing, liveability, and attract more people to a place which will benefit them financially (Everett *et al.*, 2015). Firehock (2015) argues that local governments and relevant organisations should not perceive BGI as a challenge to planning, rather as an environmentally and financially favourable approach towards more successful planning. There is an growing awareness that utilising BGI approaches such as reforesting, promoting infiltration of the floodplain and preventing development in flood-susceptible places, are more cost-efficient than building extensive flood risk management infrastructure however, the effort required to maintain BGI so as to obtain optimal benefits, is not as well-acknowledged (Firehock, 2015).

The research also found that demonstrating effectiveness was an issue. Sunderland *et al.*, (2015) notes that when planning for BGI, often the evaluation of the benefits of BGI is required to justify the costs (also known as economic valuation), this is in the form of a cost-benefit analysis. A scientifically backed "logic chain" (p. 70) can be created that demonstrates how an environmental function is connected to a beneficial service which will "be valued by people's willingness to pay for it" (p. 70); overseas research have created various categories that define the services obtained by the environment (Sunderland *et al*., 2015). Research by Hamann *et al.* (2020) describe two economic tools, B£ST and TEEB, coming from the United Kingdom and Netherlands respectively, which have been utilised in assessing BGI's long-term benefits within their local contexts, especially in planning for flood risks. Although the B£ST and TEEB tools have assisted their countries of origin, this is not yet adequately researched in Australia. Gomez (2016, as cited in Hamann *et al.,* 2020) has developed a model adapted from B£ST and TEEB to assess BGI for a retrofit project in Elwood, Australia, however no other research is currently available on how these tools could be transferable to other contexts such as in Australia's flood risk management in Australia.

This indicates that using orthodox economic calculations to assess benefits is still understudied and that as of yet, there is no internationally recognised standard valuation tool for BGI, which is reflected in the informants' comments. At present, there is still a need for more transparency around the use of the various economic tools in policy landscapes as it would arguably lead to different decisions being in planning for BGI. It should be noted that although such methods can help decision-makers in rationalising their decisions, they also include "implicit value judgements" (p. 73) around the economic benefits and costs that eventually contribute to their overall decisions (Sunderland *et al*., 2015). This suggests that economically valued projects would be favoured over BGI projects which are harder to valuate, hence BGI may not be afforded the value that it deserves. Furthermore, a study conducted by Brown & Farrelly (2009) revealed a myriad of common socio-institutional barriers to increased sustainable water management approaches, some of which reflect several of the specific flood risk management and BGI issues found in this research. These are: an uncoordinated institutional framework; regulatory framework constraints; inadequate financial and labour resources; poor organisational commitment; technocratic path dependencies and lack of political will (Brown & Farrelly, 2009). A lack of understanding of such barriers will likely prolong these issues, hence, changes need to be made within to redefine mindsets, culture and frameworks of industry and governance frameworks (Brown & Farrelly, 2009).

In addressing Research Question 3: '*How and to what extent can blue-green infrastructure be used as a more resilient and sustainable option for Brisbane's flood risk management and what are the barriers to the implementation of this infrastructure?,* the thesis argued that Brisbane's efforts in incorporating BGI for flood risk management were improving. This was highlighted by a handful of academic and consultant informants, with many of these informants strongly advocating for a higher level of BGI inclusion in Brisbane's flood risk management. The findings revealed the need for ensuring context-specific feasibility when planning for BGI, where BGI could be implemented for creek and overland flow floods but also be paired with grey infrastructure to deal with larger flood events. Informants argued that this would allow such initiatives to garner more support due to their manageability and practicality. Research by Kemp *et al.* (2015) deduced that the post-human settlement activities (farming, increased drainage infrastructure and interference with riparian flora) have increasingly altered the Brisbane River catchment and its response to floods, leading to higher channel erosion and sediment yield. Kemp *et al*. (2015) also studied the relationship between the deterioration of riparian foliage and channel erosion, observing that channel stability is contingent on riparian cover, supporting the need to reintegrate natural systems for the regulation of flood risks. Although informants were less convinced of using targeted BGI measures for river flooding, BGI also involves the preservation of natural waterways (as explained in the Literature Review), a practice which could be adapted for the Brisbane River. Stimson (1999) and Brage & Leardini (2018) emphasised that preserving the undeveloped banks of the Brisbane River is not only important in conserving the natural features of the river but is also important for flood alleviation and for overall urban sustainability.

BGI strategies were also highly recommended to be matched with robust development policies, and long-term risk indicators and incentives, indicating that informants perceived that an integrated, holistic and adaptable approach was the direction in which Brisbane's flood risk management should head towards, while also acknowledging that governance challenges restricts wider implementation. Two other key points found through the research were firstly, to keep improving environmental and flood awareness and develop streamlined community involvement; and secondly, build more partnerships with other relevant agencies and push for increased integration of resources. Such aspects would help provide more varied support and expertise to BGI initiatives and contribute to their continued maintenance and overall success. BGI implementation was observed to gain more traction at the local level, specifically, through enthusiastic individuals with local expertise in the private sector and the community that are able to mobilise the support of the wider community and champion to the government to embrace natural systems in addressing flood risks. The results found that Oxley Creek Transformation and Norman Creek 2012-2031 Projects were seen as successful examples of community-driven projects that are in partnership with BCC, where the success of these projects were believed to be partly due to BCC's support through the investing of financial and physical resources. Although an expansion of these projects is advocated, it should be highlighted that their longevity and success are also dependent on the BCC's revenue base, which experiences constraints from the state and federal government. Hence more stable financial sources need to be established before other new initiatives are implemented.

Site-specific examples like those in Brisbane are seen by Firehock (2015) to have a positive cumulative effect as they still contribute to the conservation of natural assets even at a small scale. Brown & Farrelly (2009) observed that sustainable water management practices most often take place at the local level, hence improving the capacity of local communities would be beneficial towards long-term initiatives. Furthermore, building the knowledge and technical expertise of professionals along with forming cross-sector programmes to provide learning and knowledge exchange platforms can help to propel improvements (Brown & Farrelly, 2009). Through the findings, BGI implementation appears to be more effectively administered when the community and BCC work in partnership, suggesting a growing potential for such examples in future. Hence, if BCC is proactive in integrating BGI in flood risk management strategies, then it should focus on having several successful local scale applications before implementing them at a more macro scale, to ensure that the infrastructure, support and frameworks are in place for larger applications.

9.5 Learnings from Singapore for Brisbane

This research also investigated informants' views on Singapore's flood risk management and BGI approaches and juxtaposed them against Brisbane's practices. It did this to identify areas of learning for Brisbane. This is especially important as Brisbane experiences continual urban growth, where increasing impermeable surfaces and grey infrastructure overwhelms its green spaces and will exacerbate runoff during heavy rainfall periods (Brage & Leardini, 2018; Kemp *et al*. 2015). This section further contributes to Research Question 1 and 3, where the main themes that arose are:

- Differences in governance culture and planning approach;
- Singapore's holistic BGI approach integrated into flood risk management;
- Differences in public communication and community involvement.

Singapore's centralised governance approach, innovative and proactive attitude towards planning, and visionary leadership, were revealed to be some of the key reasons for its robust flood risk management approach and BGI integration. Singapore's approach can be better understood through Firehock's (2015) explanation wherein when land planning accounts for the local ecological systems, it can guide development to areas most suited and preserve existing environmental uses while ensuring that potential corridors can be formed amongst natural features in areas already built. Additionally, as stated in the chapter on Singapore's Planning and Policy, the Public Utilities Board currently utilises a system-wide 'source-pathway-receptor' approach towards managing stormwater and reduce flood risks, which resulted from a planning and governance shift towards a holistic integration of infrastructure with BGI technology; aspects of this could be beneficial in Brisbane. Stevens *et al.* (2018) notes that utilising land use planning and urban design frameworks similar to existing operations could create difficulties in resolving flood risks if allowance is not made for the evaluation of current operations or the restructuring of current frameworks, as in the case of Brisbane. Hence, it would be useful for governments to assess best-practice systems that are indicative of features or results required for local contexts (Steven, 2018); for example, the modelling of water sensitive urban design (WSUD) practices were based on natural processes to address stormwater issues (Wong & Brown, 2009).

Singapore's whole-of-nation approach, political will, institutional efficiency, funding stability, strong multi-agency collaborations were areas that informants desired for Brisbane's local and state governments, including prioritising the interests of the community over those of developers. Additionally, informants identified Singapore's ABC Waters Programme as a strong example of targeted-BGI integration in planning, where it offers flood risk management functions along with other amenity, recreational and ecological benefits. The perspectives of the key informants largely reinforced existing literature on Singapore's approach to flood risk management and BGI. For example, Everett *et al.* (2015) recognised Singapore's efforts in optimising its drainage infrastructure with WSUD techniques to maximise its benefits. The transferability of the ABC Waters Programme was highlighted by some informants wherein Melbourne principles and technology were adapted to develop a contextually appropriate programme, hence Brisbane (and other Australian cities) could also be inspired and adopt the strengths of the ABC Waters Programme to its context. Stevens *et al*. (2018) maintains that utilising the knowledge from existing programmes can assist in planning for innovative systems, allowing design and planning professionals to evaluate issues with existing systems and identify satisfactory features that to be maintained. A key factor in the continued success of the ABC Waters Programme was the strong public relations and communication infrastructure that provides Singaporeans with succinct information about ongoing projects in their environment, which informants felt that could improve upon. Noting the constraints around certain information access and community involvement in Singapore, community involvement was found to be Brisbane's strength, indicating that perhaps its strong community driven approach could be further developed to help support wider integration of BGI in flood risk management. Overall, it was observed through the findings that adapting the strengths of Singapore's flood risk management and BGI approach for Brisbane's context and building on Brisbane's strong community engagement practices could help Brisbane develop a robust model for flood risk management.

As well as learning from other contexts, this thesis argues that there is considerable scope for improvement in Brisbane's approach to flood risk management governance. Indeed, the thesis has argued that for Brisbane's flood risk management practices to improve and suit future changing flood events, government decision-makers need to address the power imbalances that prioritises development over flood-aware planning, incorporate more robust and prescriptive flood risk management controls, developing public risk indicators around climate change and flooding factors, and focus on reconsidering their current flood risk management framework to develop a more holistic and integrated flood risk management approach. The BCC could also develop city-wide programmes that work to build and maintain a strong foundation of risk literacy to floods, which could extend to other natural hazards, as well as actively supporting and educating the public on making more informed development and property purchasing decisions based on flood risks. The BCC would also need to identify a sustainable funding mechanism dedicated for BGI initiatives and develop a structured organisational system that defines responsibilities around implementation and maintenance.

9.6 Future Research

The findings arising from this research are important in building an understanding of the current flood risk management framework and the extent and potential of BGI integration in Brisbane. As shown through the key findings of the case studies, an effective flood risk management framework is largely dependent on the local context, the governance approach and culture mindset, amongst other factors. Although the range of factors and the intricacies of their relationship presented complexities to this study, it showed the variable and adaptable nature of flood risk management, which creates challenges for governments to develop a one-size-fits-all solution.

The constraints experienced within the research indicate future research opportunities to explore the topic in further detail by gathering a larger sample of interview informants from the BCC and Singapore government agencies to obtain a wider and detailed range of views on flood risk management and BGI use. Additionally, being able to travel to the respective case study locations to conduct interviews and field observations would provide a detailed perspective on the existing and potential capacity for flood risk management and BGI improvements. Moreover, as the potential effectiveness of Oxley Creek Transformation and Norman Creek 2012-2031 Projects have been shown through this research, the research scope could also be expanded to incorporate the views of the community to further understand the role that the community can play in regulating flood risks and improving the implementation of BGI. Nevertheless, the findings of the research conclusively demonstrate there is potential in learning knowledge and techniques from a best-practice example (i.e. Singapore learnt from Melbourne) and transferring and adapting its strengths to Brisbane and other contexts, as well as for their governments to embrace and invest in innovative methods that promote a holistic approach to flood planning.

9.7 Conclusion

Expanding urbanisation, climatic uncertainty and the variable nature of riverine systems result in the unpredictable temperament of floods, requiring prompt attention in addressing the risks before the consequences become dire. This research aimed to explore the flood risk management strategies utilised in Brisbane and the potential for BGI to be used within its flood risk management framework. In addition, the research intended to provide a comparative example and elicit lessons for Brisbane through Singapore as a best-practice case study for their BGI-integrated flood risk management approach.

As the responsibilities of regulating flood risks primarily sit at the state and local levels, the findings have shown that for the effectiveness of Brisbane's flood risk management frameworks to improve, the Queensland Government has to streamline the scopes of their strategic documents in relation to flood risks and create more cohesiveness for decision-makers and other users of the documents. With the multitude of flood risk management strategies available at the local level, there are opportunities to develop a robust framework if flood planning priorities are balanced out with development priorities, and if more specific regulations are provided around flood risks. The wider community plays a key role in manifesting these strategies, hence risk literacy, flood memory and local expertise are important social components towards enhancing flood resilience. Additionally, current BGI initiatives are community-driven and government-supported, indicating a large potential for such initiatives to continue flourishing in future. In looking towards more sustainable and adaptable forms of flood risk management, Singapore's holistic and BGI-integrated flood risk management approach offers key lessons in governance, innovation, planning and public communication that can inspire Brisbane to increasingly integrate BGI as a core strategy with their flood risk management framework and improve its liveability on the floodplain.

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Appendix A: Information Sheet for Participants

[Reference Number: 20/054]
[21 May 2020]

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

THE USE OF BLUE-GREEN INFRASTRUCTURE IN BRISBANE'S URBAN FLOOD MANAGEMENT
FOR PARTICIPANTS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

What is the Aim of the Project?

The aim of this research is to analyse and assess Brisbane's flood management strategies, and to evaluate the potential for BGI to be implemented as a central flood management measure to improve the city's liveability and sustainability. This project is being undertaken as part of the requirements for the Master of Planning Programme at the University of Otago.

What Type of Participants are being sought?

This research seeks to gather the views of key stakeholders and government civil servants involved in urban flood management and blue-green infrastructure in Brisbane and Singapore.

What will Participants be Asked to Do?
Should you agree to take part in this project, you will be asked to participate in a semi-structured interview as an individual. You will be asked questions on the topics of planning and policy in terms of urban flood management, blue-green infrastructure and community responses. Interviews are expected to take place via Zoom, Skype, other video-conferencing applications available or email. It is predicted to take around 30 minutes and should not exceed the duration of 1 hour. The interviews will be audio-recorded. If at any stage you feel uncomfortable, you may decline to answer any questions, or request that the interview be terminated. Please be aware that you may decide not to take part in the project without any disadvantage to yourself of any kind.

What Data or Information will be Collected and What Use will be Made of it?
Information about urban flood management and blue-green infrastructure in Brisbane and Singapore will be collected. If you agree, the interviews will be audio-recorded will be recorded to assist the researcher in interpreting the provided information. The results of the project may be published but every attempt will be made to preserve your anonymity should you choose to remain anonymous. Raw data will be kept in secure storage for **at least 5 years** before destroyed. Any personal information held on the participants [*such as contact details, email interviews, audio or video tapes, after they have been transcribed etc.*] may be destroyed at the completion of the research even though the data derived from the research will, in most cases, be kept for much longer or possibly indefinitely.

The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve your anonymity. On the Consent Form you will be given options regarding your anonymity. Please be aware that should you wish we will make every attempt to preserve your anonymity. However, with your consent, there are some cases where it would be preferable to attribute contributions made to individual participants. It is absolutely up to you which of these options you prefer.

This project involves an open-questioning technique. The general line of questioning includes planning, flood management and Blue Green Infrastructure. The precise nature of the questions which will be asked has not been determined in advance but will depend on the way in which the interview develops. Consequently, although the University of Otago Human Ethics Committee is aware of the general areas to be explored in the interview, the Committee has not been able to review the precise questions to be used.

In the event that the line of questioning does develop in such a way that you feel hesitant or uncomfortable you are reminded of your right to decline to answer any particular question(s) and also that you may withdraw from the project at any stage without any disadvantage to yourself of any kind.

Can Participants Change their Mind and Withdraw from the Project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind. You may also request to view a transcript of your interview up until one month and may request that something that you said during the interview not be used in the thesis or subsequent publications.

What if Participants have any Questions?

If you have any questions about our project, either now or in the future, please feel free to contact either:-

Joanne Tan and **Associate Professor Douglas Hill**

School of Geography
E: tanjo989@student.otago.ac.nz

School of Geography
P: +64 3 479 8775
E: douglas.hill@otago.ac.nz

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Appendix B: Participant Consent Form

[Reference Number: 20/054]
[21 May 2020]

THE USE OF BLUE-GREEN INFRASTRUCTURE IN BRISBANE'S URBAN FLOOD MANAGEMENT
FOR PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My participation in the project is entirely voluntary;
2. I am free to withdraw from the project before its completion;
3. Personal identifying information [*audio recordings*] may be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for at least five years;
4. This project involves an open-questioning technique. The general line of questioning includes urban flood management and blue-green infrastructure in Brisbane and Singapore. The precise nature of the questions which will be asked have not been determined in advance, but will depend on the way in which the interview develops and that in the event that the line of questioning develops in such a way that I feel hesitant or uncomfortable I may decline to answer any particular question(s) and/or may withdraw from the project without any disadvantage of any kind.
5. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity, should I choose to remain anonymous.

6. I, as the participant: a) agree to being named in the research, ☐ OR;

b) would rather remain anonymous ☐

I agree to take part in this project.

....
(Signature of participant) (Date)

....

(Printed Name)

……………………………………………………..
Name of person taking consent

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.